

Review

Growing Opportunities: Considering a Thriving Agroforestry Industry in Appalachia, USA

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Abstract: The Appalachian region of the United States of America, known for its extensive forests and rich cultural heritage, faces significant socioeconomic and environmental challenges, including high poverty rates, food insecurity, and the decline of traditional industries. Agroforestry, a sustainable land-use system that combines trees, crops, and livestock, offers a practical solution by boosting biodiversity, improving soil quality, sequestering carbon, and generating diverse income streams. This article explores how agroforestry can help address economic vulnerabilities and mitigate environmental degradation in Appalachia, while also building resilience to unpredictable climate conditions. Key practices, such as silvopasture, forest farming, riparian buffer restoration, and alley cropping, offer both ecological and economic benefits, aligning with the region's traditional land-use systems. Although agroforestry offers great potential, several challenges hinder its widespread adoption, including insufficient awareness, limited technical expertise, and inadequate access to resources. Overcoming these obstacles requires targeted research, education, policy support, and community engagement. Demonstration sites and extension programs can provide landowners with practical knowledge and confidence to adopt agroforestry practices, while financial incentives, such as tax credits and payments for ecosystem services, can help reduce economic barriers. Additionally, the integration of agrivoltaics, which combines solar energy production with agroforestry, offers an innovative pathway to economic resilience by maximizing land productivity and diversifying income streams. This article emphasizes the importance of strategic investment in research, education, and policy to promote agroforestry in Appalachia, with a focus on market-driven strategies and community engagement for sustainable development.

Keywords: agroforestry; sustainability; Appalachia; biodiversity; economic resilience; forest industry; non-timber forest products; silvopasture; climate resilience; community engagement



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1. Introduction

The Appalachian region, renowned for its rich cultural heritage and extensive forest landscapes, may hold untapped potential for sustainable development through agroforestry (Castle et al., 2021). Stretching across portions of 13 states, from southern New York to northern Mississippi, Appalachia is home to diverse ecosystems and communities that rely heavily on natural resources for their survival and livelihoods. Forests cover nearly 40% of the land area, making Appalachia one of the most biodiverse temperate forest ecosystems in the world (Udawatta et al., 2019). However, despite great wealth in natural resources, environmental and socioeconomic challenges persist, including high poverty rates, food insecurity, and economic dependency on industries in decline, such as coal mining and traditional timber production (Elagib & Al-Saidi, 2020). These issues have left many communities struggling to sustain their way of life, highlighting the need for innovative approaches to regional development (Bettles et al., 2021). Agroforestry practices that traditionally integrate trees and crops to create sustainable systems have been

recognized globally for their ability to conserve biodiversity, sequester carbon, and enhance ecosystem services (Abbas et al., 2017; Cialdella et al., 2023; Dobhal et al., 2024; Kaushal et al., 2021; Nair et al., 2021; Pantera et al., 2021; Singh et al., 2021), offering a promising solution to Appalachia's challenges (Kuyah et al., 2019). By blending the ecological advantages of forest ecosystems with the productivity of agricultural practices, agroforestry may enhance biodiversity, sequester carbon, and improve soil health, and therefore, facilitate new economic opportunities for rural Appalachian communities (Fahad et al., 2022). Practices such as silvopasture, forest farming, and riparian buffer restoration have shown the potential to generate diverse income streams while promoting sustainable land use (Castle et al., 2021). Furthermore, agroforestry practices have shown the potential to play a critical role in mitigating the impacts of climate change by boosting carbon storage and enhancing the resilience of ecosystems (Abbas et al., 2017; Dobhal et al., 2024; Ghale et al., 2022; Kaushal et al., 2021; Nair et al., 2021; Pantera et al., 2021; Zomer et al., 2022). Given the region's reliance on forests and agriculture, scaling up agroforestry could provide long-term economic and environmental benefits.

A significant and persistent challenge in Appalachia is the prevalence of food deserts, areas with limited access to affordable and nutritious food that can disproportionately affect rural and underserved populations. Food deserts exacerbate health disparities and deepen the region's economic difficulties, particularly in areas already challenged with poverty and unemployment (K. E. Smith et al., 2020). Agroforestry may present a viable and innovative solution by integrating perennial crops such as fruit and nut trees into agricultural systems, including ungulate agricultural systems, thereby offering locally grown, nutritious food options to underserved populations. The practice also facilitates the cultivation of high-value non-timber forest products (NTFPs), including ginseng, mushrooms, and medicinal herbs, which hold significant economic promise while preserving the integrity of forest ecosystems (Bentrup et al., 2019). By finding a balance between agricultural productivity and ecological conservation, agroforestry can help address critical issues such as food insecurity while simultaneously creating economic pathways for communities in need (Munsell et al., 2021; Zawarus & Ortega, 2022). Additionally, the integration of agroforestry practices into existing land-use frameworks may help alleviate environmental degradation, restore biodiversity, and contribute to a healthier and more resilient regional food system. The dual ability of agroforestry to provide both ecological and economic benefits underscores its potential as a transformative tool for improving the quality of life in Appalachia.

Despite its immense promise, agroforestry remains significantly underutilized across the Appalachian region. Barriers to its adoption include a lack of awareness, technical expertise, and access to necessary resources, all of which hinder its widespread implementation. Overcoming these challenges requires a multifaceted approach that incorporates research, education, and community engagement. Research initiatives can provide the scientific basis for agroforestry practices explicitly tailored to the unique ecosystems of Appalachia, offering evidence-based strategies to maximize their effectiveness (Pattanayak et al., 2012). Meanwhile, education and extension programs can equip landowners, farmers, and practitioners with the skills and knowledge needed to adopt and sustain agroforestry practices (Hemmelgarn & Gold, 2021; Salve et al., 2022). Community engagement is equally essential, ensuring that agroforestry initiatives are aligned with local needs, priorities, and values while fostering trust and collaboration among stakeholders (Zinkhan & Mercer, 1996). The purpose of this article is to explore the transformative potential of agroforestry as a sustainable land-use strategy to address the unique environmental, economic, and social challenges facing Appalachia. It highlights the benefits of agroforestry, including enhancing biodiversity, improving food security, and fostering economic resilience, while underscoring the importance of research, education, policy support, and community engagement in achieving these outcomes. The article aims to inspire policymakers, researchers, landowners, and community members to act by adopting agroforestry practices to promote sustainable development. While drawing from a broad body of global agroforestry literature, this review critically integrates findings within the Appalachian context by examining their specific applicability, limitations, and potential adaptation needs. Rather than presenting literature descriptively, the article synthesizes evidence to highlight patterns, contrasts, and research gaps relevant to the region's unique ecological, economic, and socio-cultural conditions.

2. The Appalachian Forest Industry: A Snapshot

Appalachia's forest industry has long been a cornerstone of the region's economy, providing essential employment, raw materials, and ecosystem services that sustain local livelihoods and contribute to national markets. Renowned for its biodiversity, the region's forests support both timber production and a variety of non-timber forest products (NTFPs), forming a vital component of Appalachia's economy (Zipper et al., 2013). According to the Appalachian Regional Commission (ARC), the forest industry generates approximately \$18 billion annually, with high-demand timber products such as oak, hickory, and maple forming the bulk of this revenue (Boettner et al., 2014; Kiernan, 2024). However, despite its economic importance, the Appalachian Forest

industry faces mounting challenges that threaten its sustainability and long-term viability. Deforestation, coupled with market pressures and the far-reaching impacts of climate change, continues to strain the industry, resulting in diminished forest health and economic instability (Martin et al., 2020). Historically centered around timber harvesting for construction, furniture, and paper production, the industry has struggled to adapt to shifts in global trade dynamics and rising competition from international markets (Buehlmann et al., 2007). These challenges have led to the closure of numerous small and medium-sized sawmills, resulting in job losses and economic stagnation across many rural communities (Leakey, 1999; Schwartzman, 2023). The need to mitigate these challenges and revitalize the Appalachian Forest economy has never been more urgent. Agroforestry, which combines forestry and agriculture to create integrated, sustainable systems, may offer a promising solution by providing alternative revenue streams and promoting ecological balance alongside traditional timber production (Cialdella et al., 2023; Lasco et al., 2014; Pantera et al., 2021).

Agroforestry systems, such as forest farming and alley cropping, enable landowners to cultivate high-value non-timber forest products (NTFPs) while maintaining the benefits of forest cover and enhancing ecosystem services. Practices like forest farming allow for the production of economically lucrative crops such as ginseng, mushrooms, and medicinal herbs under the forest canopy, ensuring income generation without compromising the ecological health of the forests. Research indicates that forest farming can yield economic returns of up to \$50,000 per acre annually, depending on market conditions and the products cultivated (Salve et al., 2022). Beyond economic benefits, these practices contribute to biodiversity conservation by preserving multi-layered forest structures that support diverse wildlife populations (Santos et al., 2019; Udawatta, Rankoth, et al., 2021). Additionally, Appalachia's forests serve an indispensable role in watershed protection, as the region includes the headwaters of major rivers, including the Ohio, Tennessee, and Potomac. Riparian buffer systems, which include vegetated strips along waterways, are an agroforestry practice that provides vital ecosystem services such as pollutant filtration, soil erosion control, and streambank stabilization (Abesh et al., 2022; Kaushal et al., 2021; Udawatta, Garrett, et al., 2021; Udawatta et al., 2019). Bentrup et al. (2019) highlighted how integrating edible species like fruit and nut trees into riparian buffers not only enhances ecological functionality but also creates economic opportunities for landowners. Other Agroforestry practices such as silvopasture, which integrates trees, forage, and livestock, facilitates additional climate-resilient strategies by diversifying land use, mitigating heat stress for livestock, enhancing carbon sequestration, and improving soil health (Fahad et al., 2022; Ntawuruhunga et al., 2023; M. M. Smith et al., 2022). These practices underscore the potential for agroforestry to bolster ecological resilience and economic sustainability, providing Appalachia with a transformative approach to forest and agricultural management.

3. Innovation in Forestry and Agriculture

Traditional (historical) forestry and agricultural practices in Appalachia have operated as unilateral endeavors, often overlooking opportunities for collaboration and mutual benefit. Agroforestry may facilitate a transformative solution by integrating these practices into synergistic systems that enhance productivity, biodiversity, and resilience. Examples of agroforestry systems well-suited to the Appalachian landscape include, but are not limited to, silvopasture, alley cropping, forest farming, riparian buffers, ungulate agriculture (grazing), and agrivoltaics, each offering distinct ecological and economic advantages. These systems provide innovative pathways for landowners and farmers to address persistent challenges while maintaining the region's cultural and ecological heritage.

Silvopasture, which combines trees, forage, and livestock, creates multifunctional landscapes that enhance productivity and sustainability. By providing shade from tree canopies, silvopasture reduces heat stress on livestock and improves forage quality by maintaining soil moisture (Udawatta et al., 2019). Silvopasture systems have also been shown to sequester up to 35% more carbon compared to traditional grazing methods (Castle et al., 2021). The reduced need for external inputs such as supplemental feed and fertilizers makes silvopasture a cost-effective option for landowners. Similarly, alley cropping integrates rows of trees with crops like grains, vegetables, or berries, enhancing land-use efficiency and increasing overall productivity. The roots of nitrogen-fixing trees improve soil fertility while stabilizing the soil and preventing erosion, reducing reliance on synthetic fertilizers (Fahad et al., 2022). The complementary use of light, water, and nutrients in these systems minimizes competition and maximizes yields (Udawatta et al., 2019).

Other agroforestry practices, such as forest farming and riparian buffers, offer additional benefits tailored to Appalachian needs. Forest farming allows landowners to cultivate high-value non-timber forest products (NTFPs), including mushrooms, ginseng, and goldenseal, under the forest canopy, blending sustainable income generation with the preservation of forest ecosystems (Castle et al., 2021). Some NTFPs can yield up to \$50,000 per acre annually, depending on market conditions, making forest farming a lucrative option for many (Kaur & Tiwana, 2024; Salve et al.,

2022). Notably, while studies from other regions demonstrate significant economic returns from agroforestry, such as forest farming and silvopasture, it is critical to recognize that comparable data for Appalachia are lacking, underscoring the need for localized research to validate these findings under regional conditions. As the Brundtland Report suggests, NTFPs offer a pathway to balance ecological conservation with the economic, social, and cultural needs of forest-dependent communities (Delgado et al., 2016). In a region historically shaped by extractive industries, NTFPs offer a sustainable alternative that aligns with the Appalachian traditions of forest-based subsistence and trade. Riparian buffers, which involve planting trees and shrubs along waterways, address multiple critical environmental challenges by reducing nitrate runoff by up to 90%, stabilizing stream banks, and providing essential habitats for wildlife (Bentrup et al., 2019). Integrating economically valuable species, such as fruit or nut trees, into riparian buffers enhances their utility, creating multifunctional landscapes that benefit both the environment and local communities. These practices offer innovative solutions to soil degradation, water quality decline, and economic vulnerability while fostering climate resilience and ensuring the sustainable development of Appalachian farms and forests (Hubbart, 2021; Hubbart et al., 2022; Hubbart & Skousen, 2021). The examples provided here are admittedly global in scope and provide valuable insights. However, their application in Appalachia requires careful consideration of the region's distinct topography, land-use history, and market dynamics, which may influence both the feasibility and outcomes of such practices.

4. Addressing Food Deserts

Food deserts, defined as areas with limited access to affordable and nutritious food, remain a significant challenge in Appalachia, where rural isolation, economic disparities, and insufficient infrastructure exacerbate food insecurity (Dean-Witt & Hardin-Fanning, 2020). Agroforestry presents a transformative approach to addressing these challenges by integrating sustainable food production into the existing landscape, thereby enhancing ecological and community resilience. Community orchards are one such agroforestry strategy, transforming underutilized spaces into hubs for fruit and nut production. These orchards, which include apples, pear, walnut, and chestnut trees, provide fresh produce, enhancing food availability and broadening local diets. Beyond their nutritional benefits, community orchards foster a sense of ownership and engagement among residents, strengthening social connections and environmental stewardship (Bentrup et al., 2019). Moreover, these orchards require minimal maintenance and provide long-term productivity, making them well-suited for both rural and urban Appalachian settings. Economically, surplus produce from community orchards can be sold at local markets, creating revenue streams for residents. Educational initiatives tied to orchards, such as partnerships with schools and local organizations, may further enhance community impact by teaching sustainable agriculture and promoting healthy eating habits (Koempel et al., 2022). By establishing orchards on public lands or through partnerships with private landowners, Appalachian communities can effectively reduce food deserts and foster greater self-reliance.

An innovative and progressive agroforestry technique involves establishing riparian buffers that incorporate fruit- and nut-bearing plants, such as elderberries, hazelnuts, and pawpaws, in vegetative zones adjacent to watercourses. Traditionally implemented to improve water quality and reduce erosion, riparian buffers offer additional functionality by addressing food insecurity and generating economic opportunities. These buffers filter agricultural runoff, reducing nutrient pollution and protecting aquatic habitats while simultaneously providing locally grown food resources for nearby communities (Castle et al., 2021). Studies have demonstrated that riparian buffers can reduce nitrate runoff by up to 90%, significantly enhancing the health of adjacent streams and rivers (Bentrup et al., 2019). The integration of edible plants into these buffers not only improves biodiversity but also aligns with Appalachian traditions of utilizing native species, ensuring cultural relevance and community acceptance. The sale of harvested products from edible riparian buffers can provide supplementary income for farmers and landowners, enhancing their economic resilience. By adopting community orchards and edible riparian buffers, Appalachian communities can tackle food deserts through solutions that are both locally driven and ecologically sound. Agroforestry's framework combines environmental restoration and human well-being, yielding impactful, culturally relevant, and sustainable long-term practices.

5. The Need for Research: Advancing a Conceptual Framework and Identifying Regional Priorities

Appalachian agroforestry success depends on substantial research that identifies best practices, overcomes obstacles, and optimizes environmental, economic, and social outcomes. One critical area of focus is the economic viability of agroforestry systems. Uncertainty about profitability remains a significant barrier for landowners considering these practices, as they must have compelling evidence of financial returns before transitioning. Existing studies suggest that systems such as silvopasture and forest farming can generate substantial economic benefits, but

detailed, region-specific, and physiographic analyses are crucial for validating these claims (Rodrigues Maia, 2023). For example, research could model the costs and benefits of implementing community orchards, riparian buffers, and silvopasture systems, providing precise data on return on investment, scalability, and long-term sustainability. These insights would not only reduce economic uncertainty (financial risk) but also empower landowners to make informed decisions about adopting agroforestry practices.

The literature consistently identifies knowledge gaps, policy barriers, and socio-cultural factors as obstacles to agroforestry adoption; however, few studies directly explore these dimensions within Appalachian communities, revealing a specific research gap that warrants urgent attention. Equally important is understanding the ecological impacts of agroforestry, particularly under Appalachian conditions. Agroforestry systems are known to enhance ecosystem services such as carbon sequestration, soil conservation, and biodiversity (Castle et al., 2022). However, more localized studies are needed to quantify these benefits in the complex topography, diverse microclimates, and distinct land-use histories of Appalachia. For example, research could investigate how alley cropping with native tree species affects soil nutrient dynamics and microbial communities, or how agroforestry systems contribute to watershed health and forest restoration. Additionally, the resilience of these systems to climate stressors like droughts, pests, and shifting weather patterns requires further investigation to ensure their sustainability over time (Pancholi et al., 2023). Such studies would provide the scientific basis for tailoring agroforestry practices to Appalachian landscapes, maximizing their environmental and economic potential while addressing the region's unique ecological challenges. Together, these studies suggest that agroforestry systems enhance ecosystem services globally; yet their performance in Appalachia's complex, mountainous ecosystems remain largely untested, necessitating regionally focused ecological studies. Tailored practices may enhance the viability of agroforestry as a sustainable land-use strategy for both landowners and policymakers in the region.

The socio-cultural factors influencing the adoption of agroforestry also require significant research attention. Understanding the traditions, perceptions, and values of Appalachian landowners and farmers is essential for developing strategies that align with community needs and priorities. Participatory research methods, which engage stakeholders directly, can inform decision-making processes and identify barriers to adoption (Mercer, 2004). Understanding the potential drivers of agroforestry adoption is essential for identifying the social and environmental factors that hinder or facilitate its implementation, providing a foundation for designing and implementing effective policies (Zabala et al., 2025). Notably, while this review integrates diverse disciplinary perspectives, it does not attempt to construct a formalized theoretical model. Advancing the field would benefit from the development of regionally grounded theoretical or decision-support frameworks that can more systematically guide agroforestry adoption, assess ecosystem service trade-offs, and inform policy design in the Appalachian context. Additionally, technological innovations such as remote sensing, GIS mapping, and precision agriculture hold promise for revolutionizing agroforestry practices by enabling efficient monitoring of tree health, soil conditions, and crop yields. Furthermore, research into policy and institutional support is crucial for creating an enabling environment for the adoption of agroforestry. This evaluation includes existing incentive programs like cost-sharing initiatives and tax credits, identifying gaps, and drawing lessons from successful policies in other regions (Gonçalves et al., 2021). By addressing these interconnected research priorities, Appalachian policymakers may be able to facilitate agroforestry's transformative potential, fostering collaboration among academic institutions, government agencies, nonprofits, and local stakeholders to drive innovation and achieve sustainable, community-driven outcomes.

It is worthwhile restating that currently there is no consolidated or comprehensive database documenting integrated agroforestry practices, outcomes, or adoption rates, case studies, and even pictorial representations of agroforestry specific to the Appalachian region. This significant gap in empirical data underscores the need for foundational research, including site-specific field trials, economic modeling, ecological assessments, and socio-cultural studies. The absence of such datasets has limited the ability to conduct statistical analyses or present regionally tailored empirical data within this review. Therefore, a core purpose of this article is to synthesize the broader body of agroforestry literature, identify its potential applicability to Appalachia, and, critically, highlight the urgent need for systematic research efforts to build the datasets necessary for evidence-based policy, practice, and investment. The development of these datasets and corresponding analyses represents a critical next step beyond the scope of the current work.

6. The Integration of Agrivoltaics into Agroforestry Systems

Combining solar energy production with agriculture, known as agrivoltaics, enables landowners to boost productivity by generating energy and crops simultaneously. The integration of agrivoltaics into agroforestry systems offers a contemporaneous and timely approach to addressing economic and environmental challenges while promoting diversified income and

sustainable land use. When combined with agroforestry practices, this integration creates synergistic systems that enhance land-use efficiency and resilience. For example, shade-tolerant crops or medicinal herbs may thrive beneath solar panels, while silvopasture systems can incorporate livestock grazing alongside tree growth and renewable energy production. Research has shown that agrivoltaic systems can increase land-use efficiency by up to 70%, demonstrating their potential to meet both energy and agricultural needs simultaneously (Dupraz et al., 2011). Agrivoltaics can increase annual net revenues for landowners by 300–5,000% compared to farming alone. This approach also enhances financial resilience, particularly for crops vulnerable to weather and market fluctuations, by diversifying income streams and boosting worst-case net revenues by 48–53% (Cuppari et al., 2021). Given the economic challenges in Appalachia, agrivoltaics may provide a sustainable approach to enhance farm profitability while maintaining agricultural productivity. By carefully designing these systems to optimize light distribution and resource utilization, landowners can achieve both economic and ecological benefits, ensuring long-term sustainability and resilience.

Beyond its economic potential, the integration of agrivoltaics into agroforestry systems addresses critical socioeconomic challenges, particularly in rural regions such as Appalachia. By combining renewable energy with agriculture and forestry, these systems generate multiple income streams and create new job opportunities. For example, solar energy projects often spur local employment in installation, maintenance, and technical support, offering high-paying jobs that can revitalize rural economies (Proctor et al., 2020). Additionally, the energy produced can reduce on-farm electricity costs, freeing up resources for further investment in agricultural operations. These systems also contribute to energy equity by providing access to renewable energy in underserved areas. Furthermore, agrivoltaic agroforestry systems align with traditional land-use practices and cultural values, fostering local acceptance and encouraging broader adoption. The socioeconomic benefits, coupled with its ecological advantages, make this approach a compelling strategy for addressing poverty and economic instability while promoting environmental stewardship.

From an environmental perspective, agrivoltaic agroforestry systems enhance ecosystem services, mitigate climate change, and improve resource efficiency. Solar panels provide shade, creating a microclimate that reduces soil temperature and evapotranspiration, thereby conserving water and improving soil health. Studies indicate that such systems can reduce irrigation needs by up to 30%, a significant benefit in water-scarce regions and during drought conditions (Barron-Gafford et al., 2019). However, realizing the full potential of integrated agroforestry and agrivoltaics systems requires robust research and supportive policies. Studies must focus on optimizing designs to balance energy generation with agricultural and forestry outputs. At the same time, policies should provide financial incentives, such as grants, tax credits, and subsidies, to lower the barriers to adoption. With concerted efforts from researchers, policymakers, and communities, agrivoltaics in agroforestry can serve as a transformative tool for diversified income, socioeconomic upliftment, and environmental resilience.

7. The Role of Education, Extension, and Community Engagement

Education serves as the cornerstone for advancing the adoption of agroforestry practices in Appalachia, addressing critical knowledge gaps that often hinder the transition to sustainable land use. Comprehensive education initiatives empower farmers, foresters, community leaders, policymakers, and consumers with the technical expertise, economic rationale, and ecological benefits needed to implement agroforestry systems effectively. Integrating agroforestry into formal education and extension services not only builds the capacity of current practitioners but also inspires future generations of researchers and innovators, ensuring the long-term sustainability of agroforestry practices. University academic programs, community organizations, and cooperative extension can lead this effort by providing tailored educational programs that align with the region's unique environmental and socioeconomic conditions.

Extension programs represent one of the most impactful approaches to agroforestry education. These programs bridge the gap between scientific research and practical application, offering hands-on training, demonstration plots, and workshops to landowners and agricultural professionals (Pattanayak et al., 2012). For example, demonstration projects on silvopasture and riparian buffer systems, which incorporate edible species, can guide farmers with the knowledge of how to align agricultural productivity with ecological goals. Additionally, collaborative workshops offer opportunities for peer-to-peer learning, enabling local farmers to apply practical agroforestry techniques and exchange best practices. Incorporating agroforestry into school and university curricula is another critical strategy for fostering innovation and expertise. Programs in environmental science, agriculture, and forestry can incorporate agroforestry principles, equipping students with the interdisciplinary knowledge required to address complex sustainability challenges. Experiential learning opportunities, such as internships and fieldwork, enhance students' ability to apply theoretical concepts in real-world contexts, preparing a new generation of practitioners to advance sustainable development (Denham et al., 2004).

Community engagement is foundational to the success of agroforestry initiatives, as it ensures that strategies and practices align with the unique needs, priorities, and values of local stakeholders (Hubbart, 2023a, 2023b, 2024a, 2024b). Actively involving stakeholders in the planning, implementation, and management of agroforestry systems fosters trust, collaboration, and shared responsibility, enabling communities to take ownership of sustainable land-use practices. This participatory approach is particularly critical in Appalachia, where diverse cultural traditions, historical contexts, and socioeconomic challenges significantly influence land management decisions (Carlson, 2019). By tailoring engagement efforts to the specific characteristics of the region, agroforestry practitioners can build stronger connections with communities and encourage broader adoption of innovative practices. Cultural relevance is another critical component of successful community engagement. Appalachia's rich heritage and traditions can be leveraged to enhance the acceptance and impact of agroforestry initiatives. Incorporating native species into agroforestry systems not only supports biodiversity but also resonates with the cultural identity of local communities (Castle et al., 2021). Storytelling, an essential Appalachian tradition, offers a powerful tool for sharing success stories, building trust, and inspiring broader adoption of agroforestry practices. Moreover, engaging youth through education-focused initiatives, such as school curricula and student-managed projects like community gardens and orchards, ensures the sustainability of these efforts by cultivating a new generation of informed practitioners (Koempel et al., 2022). Digital tools and online platforms further enhance engagement by overcoming geographic barriers, connecting dispersed communities, and providing accessible resources, expert advice, and peer support (Williams et al., 2010).

8. Policy and Funding Support

The policy recommendations presented here are intended to strike a balance between established, operational mechanisms and forward-looking, innovative approaches tailored to Appalachia's specific challenges. Recognizing the need for both immediate practical actions and longer-term systemic change, the recommendations draw on successful programs while proposing adaptive strategies that leverage emerging markets, technologies, and cooperative models. This dual approach may provide landowners, communities, and policymakers with actionable pathways that are both feasible within existing frameworks and capable of driving transformative outcomes. Policy and funding support play a crucial role in scaling up agroforestry initiatives across Appalachia, addressing the region's socioeconomic and environmental challenges. A well-structured policy framework coupled with robust funding mechanisms should lower barriers to adoption, create diversified income opportunities, and enhance environmental resilience. Financial incentives remain crucial in promoting the adoption of agroforestry. Cost-sharing programs for agroforestry establishment, such as tree planting, silvopasture development, and riparian buffer restoration, may alleviate the initial financial burden on landowners (Bettles et al., 2021). Tax credits for ecosystem services, including carbon sequestration and biodiversity conservation, may provide another avenue for demonstrating the economic value of ecological stewardship (Castle et al., 2021). Additionally, payments for ecosystem services (PES) schemes may incentivize sustainable practices by rewarding landowners for contributing to water quality improvement, soil health, and carbon storage (Mukhlis et al., 2022). For example, agroforestry presents significant opportunities for landowners to participate in the emerging forest carbon market. By adopting agroforestry, landowners can generate income from carbon credits while continuing to earn revenue from timber, non-timber forest products (NTFPs) like ginseng and mushrooms, and agricultural yields. This diversification reduces financial risk and increases long-term economic stability. Recent developments in carbon offset programs are making participation increasingly viable, allowing landowners to generate revenue while promoting sustainable land management (Gazal et al., 2024).

Investments in research and education are cornerstones to the successful broad-scale adoption of agroforestry practices. Research grants and other funding mechanisms should be developed that support region-specific studies on the economic viability and ecological benefits of agroforestry systems, providing landowners with data-driven insights (Brown et al., 2018). For example, pilot projects and demonstration sites funded by grants can showcase best practices, while education-focused funding could expand extension services, training workshops, and technical support programs for practitioners (Pattanayak et al., 2012). Agroforestry also holds significant potential for addressing socioeconomic disparities in Appalachia. By diversifying income streams through the cultivation of high-value non-timber forest products (NTFPs) like ginseng, mushrooms, and medicinal herbs, agroforestry provides alternative revenue opportunities for communities affected by declining industries (Kaur & Tiwana, 2024).

Collaborations between public and private entities could mobilize resources and expertise, driving large-scale adoption of agroforestry. Partnerships with private forestry companies, agricultural cooperatives, and renewable energy firms can pool funding and technical knowledge, while nonprofits can facilitate community engagement and capacity building. For example,

agroforestry cooperatives focused on NTFPs can help aggregate production, secure fair market access, and enhance economic returns for small-scale farmers (Koempel et al., 2022). Integrating agroforestry into broader environmental and economic policies can amplify its impact. Policies aligning with the USDA's Conservation Reserve Program (CRP) or international initiatives like the United Nations Sustainable Development Goals (SDGs) may provide additional funding opportunities and elevate the visibility of Appalachian agroforestry efforts (Santiago-Freijanes et al., 2021). By prioritizing these strategies and others not presented here, the potential for agroforestry to foster resilient communities and sustainable landscapes may be realized in Appalachia.

9. Synthesis: Advancing Agroforestry in Appalachia

The practical significance of advancing agroforestry in Appalachia can be understood at three critical levels. First, the importance of this work lies in agroforestry's potential to address the region's interrelated environmental, economic, and social challenges, including degraded ecosystems, economic stagnation, and food insecurity. Second, the necessity is underscored by the current absence of regionally tailored research, data, and adoption frameworks, which limit informed decision-making and impede policy development. Finally, the feasibility of advancing agroforestry is demonstrated through existing federal programs, emerging market mechanisms, and community engagement strategies that offer practical and scalable pathways for implementation. Together, these dimensions highlight the urgency and opportunity for coordinated action by researchers, policymakers, and practitioners. This review, therefore, integrates global evidence with Appalachian realities, critically identifying both the promise and the pronounced research gaps that must be addressed to translate the potential of agroforestry into practice in the region.

The adoption of agroforestry practices in Appalachia presents a transformative opportunity to address the region's environmental, economic, and social challenges by integrating sustainable land-use practices with community-driven approaches. Some of the most critical needs for advancing agroforestry in the region include (1) the establishment of agroforestry demonstration sites with community-engaged field days, (2) robust policy and funding support, (3) enhanced educational initiatives, and (4) strategic marketing.

- (1) *Establishing Agroforestry Demonstration Sites with Community-Engaged Field Days:* Demonstration of agroforestry sites represents a vital tool for showcasing the practical applications of agroforestry practices and fostering adoption. Research shows that participatory workshops and practical demonstrations are among the most effective ways to bridge the gap between theoretical knowledge and actionable practice (Kruger et al., 2012). Community-engaged field days at these sites provide hands-on learning opportunities, allowing participants to observe the benefits of silvopasture, agrivoltaics, riparian buffers, and forest farming in real-world contexts. Effective community engagement ensures that agroforestry initiatives align with local traditions, values, and priorities. Participatory approaches that involve stakeholders in the planning, implementation, and management of agroforestry systems foster trust, collaboration, and ownership (Mukhlis et al., 2022). Digital tools, including online platforms and mobile applications, provide accessible resources and peer support, overcoming geographic barriers and connecting dispersed communities (Williams et al., 2010). Demonstration sites also act as platforms for piloting innovative practices, such as the integration of agroforestry with agrivoltaic systems, which have been shown to enhance land-use efficiency and diversify income streams (Barron-Gafford et al., 2019).
- (2) *Robust Policy and Funding Support:* Scaling agroforestry requires a well-structured policy framework and financial incentives to reduce barriers to adoption. Cost-sharing programs, tax credits for ecosystem services, and payments for ecosystem services (PES) are critical mechanisms to support landowners in transitioning to agroforestry systems (Bettles et al., 2021). Policies aligning with national and international initiatives, such as the USDA's Conservation Reserve Program and the United Nations Sustainable Development Goals, can elevate agroforestry's visibility and unlock additional funding opportunities (Castle et al., 2021). Collaborations between public and private entities, including forestry companies, agricultural cooperatives, and renewable energy firms, can further mobilize resources and expertise. Nonprofits play a crucial role in advocating for policy reforms and facilitating grassroots engagement, ensuring equitable access to funding and technical support (Santiago-Freijanes et al., 2021).
- (3) *Enhanced Educational Initiatives:* Education is foundational for agroforestry's success, equipping stakeholders with the knowledge and skills needed to innovate and implement sustainable practices. Extension programs offering hands-on training, workshops, and technical support are essential for bridging knowledge gaps and building practitioner capacity (Pattanayak et al., 2012). In addition to technical training, increasing landowners' awareness

of financial incentives and support programs, such as cost-share programs, tax incentives, and grants, can help reduce economic barriers to agroforestry adoption. Many landowners remain unaware of available assistance programs, which limits participation in sustainable practices (Butler et al., 2014). Providing clear, accessible information about these opportunities through extension can facilitate greater adoption of agroforestry. Integrating agroforestry principles into school and university curricula fosters innovation and ensures the sustainability of these efforts by cultivating a new generation of informed practitioners (Koempel et al., 2022). Demonstration sites, in combination with experiential learning opportunities such as internships, provide students with real-world experience, preparing them to address complex sustainability challenges.

- (4) *Strategic Marketing*: A well-developed marketing strategy is crucial for creating consumer demand and ensuring the financial viability of agroforestry-based products. Farmers, ranchers, and forest owners are increasingly interested in integrating fruit, nuts, root crops, mushrooms, and other specialty crops into their production systems using agroforestry practices. However, many producers seek information and market connections before committing to these practices (USDA National Agroforestry Center, 2021). Establishing cooperative networks, farm-to-market programs, and branding Appalachian agroforestry products, such as specialty crops, non-timber forest products (e.g., ginseng, mushrooms, nuts) and sustainably raised livestock, can help differentiate them in local and national markets. Additionally, strengthening value chains through regional food hubs, direct-to-consumer marketing, and partnerships with retailers can improve profitability and encourage broader adoption of agroforestry.

By addressing these and other critical needs, the transformative potential of agroforestry may be realized in Appalachia, promoting sustainable land use, economic resilience, and preservation of the rich cultural heritage for a more sustainable future. In addition to established strategies reported here, advancing agroforestry in Appalachia will also benefit from innovative approaches such as integrating agrivoltaics, leveraging carbon markets and payments for ecosystem services, fostering cooperative models for non-timber forest products, and utilizing digital platforms and participatory demonstrations to accelerate adoption. These scalable and regionally tailored strategies complement existing frameworks and can help catalyze transformative outcomes for Appalachian communities.

10. Conclusions

The development of a thriving agroforestry industry in Appalachia may offer a transformative opportunity to address the region's interconnected environmental, economic, and social challenges. By integrating trees, shrubs, ungulate agriculture, specialty crops, agrivoltaics, and many other production systems into agricultural landscapes, agroforestry combines ecological benefits with economic incentives, making it a powerful tool for sustainable development. These systems are particularly well-suited to Appalachia's unique environmental and cultural landscape, where deforestation, soil degradation, and food insecurity remain pressing issues. The cultivation of high-value non-timber forest products (NTFPs), including ginseng, mushrooms, and medicinal herbs, offers a viable alternative to declining industries like coal mining and traditional timber production. These opportunities not only address environmental sustainability but also support economic resilience in rural communities.

While the opportunities presented by agroforestry in Appalachia are compelling, it is essential to recognize that the current knowledge base lacks region-specific empirical data, integrated assessments, and statistical analyses necessary to fully validate these opportunities under Appalachian conditions. This review has been undertaken to address this deficiency by synthesizing global literature, identifying applicable practices, and framing the potential pathways forward. The generation of new research data, including experimental trials, economic feasibility studies, and ecological impact assessments, is urgently needed. By spotlighting these knowledge gaps, the article seeks to catalyze the research community, policymakers, and practitioners to prioritize the development of these critical datasets, which are foundational for informed decision-making and the successful establishment of a thriving agroforestry sector in Appalachia.

Realizing the full potential of agroforestry in Appalachia requires a concerted and collaborative effort among policymakers, researchers, educators, and local communities. Education and community engagement are pivotal to fostering the widespread adoption of agroforestry practices. Tailored extension services, participatory workshops, and experiential learning programs can bridge knowledge gaps and empower stakeholders with the skills necessary to implement agroforestry systems effectively. Policy and funding support are equally essential; cost-sharing programs, tax credits for ecosystem services, and grants for research and education can significantly reduce barriers for landowners. Public-private partnerships and alignment with broader strategies like the USDA Conservation Reserve Program may further strengthen these efforts.

Simultaneously, rigorous research on economic feasibility, ecological impacts, and socio-cultural factors can provide a robust scientific foundation for scaling agroforestry practices. By prioritizing inclusivity and leveraging the region's natural and cultural resources, Appalachia can position itself as a leader in sustainable agroforestry practices, creating a future marked by resilience, innovation, and shared prosperity.

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References

- Abbas, F., Hammad, H. M., Fahad, S., Cerdà, A., Rizwan, M., Farhad, W., Ehsan, S., & Bakhat, H. F. (2017). Agroforestry: A sustainable environmental practice for carbon sequestration under the climate change scenarios—a review. *Environmental Science and Pollution Research*, 24, 11177–11191. <https://doi.org/10.1007/s11356-017-8687-0>
- Abesh, B. F., Jin, L., & Hubbard, J. A. (2022). Predicting climate change impacts on water balance components of a mountainous watershed in the Northeastern USA. *Water*, 14(20), 3349. <https://doi.org/10.3390/w14203349>
- Barron-Gafford, G. A., Pavao-Zuckerman, M. A., Minor, R. L., Sutter, L. F., Barnett-Moreno, I., Blackett, D. T., Thompson, M., Dimond, K., Gerlak, A. K., Nabhan, G. P., & Macknick, J. E. (2019). Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands. *Nature Sustainability*, 2, 848–855. <https://doi.org/10.1038/s41893-019-0364-5>
- Bentrup, G., Hopwood, J., Adamson, N. L., & Vaughan, M. (2019). Temperate agroforestry systems and insect pollinators: A review. *Forests*, 10(11), 981. <https://doi.org/10.3390/f10110981>
- Bettles, J., Battisti, D. S., Cook-Patton, S. C., Kroeger, T., Spector, J. T., Wolff, N. H., & Masuda, Y. J. (2021). Agroforestry and non-state actors: A review. *Forest Policy and Economics*, 130, 102538. <https://doi.org/10.1016/j.forpol.2021.102538>
- Boettner, F., Hansen, E., Clingerman, J., Hereford, A., Zegre, S., Martin, R., Askins, N., Deng, J., Anderson, J., Collins, A., Harris, T., Jackson, R., LaFone, F., Lamont, S., Strager, J., Strager, M., Veselka, W., Zegre, N., Abdalla, C., & Goetz, S. J. (2014). *An assessment of natural assets in the Appalachian region: Water resources*. Appalachian Regional Commission. <https://www.arc.gov/wp-content/uploads/2020/06/AssessmentofNaturalAssetsintheAppalachian-Region-WaterResources.pdf>
- Brown, S. E., Miller, D. C., Ordonez, P. J., & Baylis, K. (2018). Evidence for the impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being in high-income countries: A systematic map protocol. *Environmental Evidence*, 7, 24. <https://doi.org/10.1186/s13750-018-0136-0>
- Buehlmann, U., Bumgardner, M., Schuler, A., & Barford, M. (2007). Assessing the impacts of global competition on the Appalachian hardwood industry. *Forest Products Journal*, 57(3), 89–93. https://www.nrs.fs.usda.gov/pubs/jrnl/2007/nrs_2007_buehlmann_001.pdf
- Butler, B. J., Markowski-Lindsay, M., Snyder, S., Catanzaro, P., Kittredge, D. B., Andrejczyk, K., Dickinson, B. J., Eryilmaz, D., Hewes, J. H., Randler, P., Tadler, D., & Kilgore, M. A. (2014). Effectiveness of landowner assistance activities: An examination of the USDA Forest Service's Forest Stewardship Program. *Journal of Forestry*, 112(2), 187–197. <https://doi.org/10.5849/jof.13-066>
- Carlson, E. B. (2019). *“There is wealth in the struggle”: Unearthing and embracing community knowledges through organized work in Appalachia*. [Doctor Dissertation, Perdue University]. <https://dx.doi.org/10.25394/PGS.8292149.V1>
- Castle, S. E., Miller, D. C., Merten, N., Ordonez, P. J., & Baylis, K. (2022). Evidence for the impacts of agroforestry on ecosystem services and human well-being in high-income countries: A systematic map. *Environmental Evidence*, 11, 10. <https://doi.org/10.1186/s13750-022-00260-4>
- Castle, S. E., Miller, D. C., Ordonez, P. J., Baylis, K., & Hughes, K. (2021). The impacts of agroforestry interventions on agricultural productivity, ecosystem services, and human well-being in low- and middle-income countries: A systematic review. *Campbell Systematic Reviews*, 17(2), e1167. <https://doi.org/10.1002/cl2.1167>
- Cialdella, N., Jacobson, M., & Penot, E. (2023). Economics of agroforestry: Links between nature and society. *Agroforestry Systems*, 97, 273–277. <https://doi.org/10.1007/s10457-023-00829-z>
- Cuppari, R. I., Higgins, C. W., & Characklis, G. W. (2021). Agrivoltaics and weather risk: A diversification strategy for landowners. *Applied Energy*, 291, 116809. <https://doi.org/10.1016/j.apenergy.2021.116809>
- Dean-Witt, C., & Hardin-Fanning, F. (2020). P41 Exploring the stigma of childhood food insecurity in Appalachia. *Journal of Nutrition Education and Behavior*, 52(7), S34–S35. <https://doi.org/10.1016/j.jneb.2020.04.086>
- Delgado, T. S., McCall, M. K., & López-Binquíst, C. (2016). Recognized but not supported: Assessing the incorporation of non-timber forest products into Mexican forest policy. *Forest Policy and Economics*, 71, 36–42. <https://doi.org/10.1016/j.forpol.2016.07.002>

- Denham, S. A., Meyer, M. G., Toborg, M. A., & Mande, M. J. (2004). Providing health education to Appalachia populations. *Holistic Nursing Practice*, 18(6), 293–301. <https://doi.org/10.1097/00004650-200411000-00005>
- Dobhal, S., Kumar, R., Bhardwaj, A. K., Chavan, S. B., Uthappa, A. R., Kumar, M., Singh, A., Jinger, D., Rawat, P., Handa, A. K., & Ramawat, N. (2024). Global assessment of production benefits and risk reduction in agroforestry during extreme weather events under climate change scenarios. *Frontiers in Forests and Global Change*, 7. <https://doi.org/10.3389/ffgc.2024.1379741>
- Dupraz, C., Marrou, H., Talbot, G., Dufour, L., Nogier, A., & Ferard, Y. (2011). Combining solar photovoltaic panels and food crops for optimising land use: Towards new agrivoltaic schemes. *Renewable Energy*, 36(10), 2725–2732. <https://doi.org/10.1016/j.renene.2011.03.005>
- Elagib, N. A., & Al-Saidi, M. (2020). Balancing the benefits from the water–energy–land–food nexus through agroforestry in the Sahel. *Science of the Total Environment*, 742, 140509. <https://doi.org/10.1016/j.scitotenv.2020.140509>
- Fahad, S., Chavan, S. B., Chichaghare, A. R., Uthappa, A. R., Kumar, M., Kakade, V., Pradhan, A., Jinger, D., Rawale, G., Yadav, D. K., Kumar, V., Farooq, T. H., Ali, B., Sawant, A. V., Saud, S., Chen, S., & Poczai, P. (2022). Agroforestry systems for soil health improvement and maintenance. *Sustainability*, 14(22), 14877. <https://doi.org/10.3390/su142214877>
- Gazal, K. A., Hwang, J., & Eastman, B. (2024). West Virginia forest landowners' preferences for forest carbon offset programs. *Trees, Forests and People*, 18, 100683. <https://doi.org/10.1016/j.tfp.2024.100683>
- Ghale, B., Mitra, E., Sodhi, H. S., Verma, A. K., & Kumar, S. (2022). Carbon sequestration potential of agroforestry systems and its potential in climate change mitigation. *Water, Air, & Soil Pollution*, 233, 228. <https://doi.org/10.1007/s11270-022-05689-4>
- Gonçalves, C. D. B. Q., Schlindwein, M. M., & Martinelli, G. D. C. (2021). Agroforestry systems: A systematic review focusing on traditional indigenous practices, food and nutrition security, economic viability, and the role of women. *Sustainability*, 13(20), 11397. <https://doi.org/10.3390/su132011397>
- Hemmelgarn, H. L., & Gold, M. A. (2021). Agroforestry education and training. In H. E. G. Garrett, S. & Jose, M. A. Gold (Eds.), *North American Agroforestry* (3rd ed., pp.543–554). ACSESS. <https://doi.org/10.1002/9780891183785.ch19>
- Hubbart, J. A. (2021). Improving best management practice decisions in mixed land use and/or municipal watersheds: Should approaches be standardized? *Land*, 10(12), 1402. <https://doi.org/10.3390/land10121402>
- Hubbart, J. A. (2023a). Considering use-inspired design and tangible impacts in the agricultural sector. *Open Access Journal of Agricultural Research*, 8(4). <https://doi.org/10.23880/oajar-16000323>
- Hubbart, J. A. (2023b). Harmonizing science and society: A change management approach to align scientific endeavors with societal needs. *Sustainability*, 15(21), 15233. <https://doi.org/10.3390/su152115233>
- Hubbart, J. A. (2024a). The importance of stakeholder engagement across market domains. *Journal of Global Entrepreneurial Management*, 2(1), 1–7. <https://scitechjournals.com/articles/the-importance-of-stakeholder-engagement-across-market-domains.pdf>
- Hubbart, J. A. (2024b). Maximizing research impact in higher education: An approach to identify essential stakeholders and ensure use-inspired outcomes. *Journal of Humanities and Education Development*, 6(1), 43–50. <https://doi.org/10.22161/jhed.6.1.6>
- Hubbart, J. A., Kellner, E., & Petersen, F. (2022). A 22-site comparison of land-use practices, *E-coli* and enterococci concentrations. *International Journal of Environmental Research and Public Health*, 19(21), 13907. <https://doi.org/10.3390/ijerph192113907>
- Hubbart, J. A., & Skousen, J. (2021). *Effects of Legacy Coal Mining in Contemporary Watersheds: A West Virginia Case Study*. In L. McLean (Ed.), *Reclamation Matters, Spring 2021* (pp. 30–35). DEL Communications Inc. <https://www.asrs.us/wp-content/uploads/2021/08/Reclamation-Matters-Spring-2021.pdf>
- Kaur, M., & Tiwana, B. S. (2024). Agroforestry methods as a substitute for sustainability in the economy and environment. *International Journal For Multidisciplinary Research*, 6(4). <https://doi.org/10.36948/ijfmr.2024.v06i04.26040>
- Kaushal, R., Mandal, D., Panwar, P., Rajkumar, Kumar, P., Tomar, J. M. S., & Mehta, H. (2021). Soil and water conservation benefits of agroforestry. In P. K. Shit, H. R. Pourghasemi, P. P. Adhikary, G. S. Bhunia, & V. P. Sati (Eds.), *Forest resources resilience and conflicts* (pp. 259–275). Elsevier. <https://doi.org/10.1016/b978-0-12-822931-6.00020-4>
- Kiernan, P. (2024, October 29). *Logging is a way of life in Appalachia. It's hanging on by a thread*. The Wall Street Journal. <https://www.wsj.com/economy/trade/logging-is-a-way-of-life-in-appalachia-its-hanging-on-by-a-thread-e9a5f0a5?msocid=3bb01356a9ca61db1b6f073aa85860cd>
- Koempel, A., Brislen, L., Jacobsen, K., Clouser, J., Vundi, N., Li, J., Williams, M. A., & Williams, M. V. (2022). Growing health: Building partnerships in healthcare and food systems for improved food access in Appalachia. *Journal of Agriculture, Food Systems, and Community Development*, 11(4), 261–271. <https://doi.org/10.5304/jafscd.2022.114.022>
- Kruger, T. M., Swanson, M., Davis, R. E., Wright, S., Dollarhide, K., & Schoenberg, N. E. (2012). Formative research conducted in rural appalachia to inform a community physical activity intervention. *American Journal of Health Promotion*, 26(3), 143–151. <https://doi.org/10.4278/ajhp.091223-qual-399>
- Kuyah, S., Whitney, C. W., Jonsson, M., Sileshi, G. W., Öborn, I., Muthuri, C. W., & Luedeling, E. (2019). Agroforestry delivers a win-win solution for ecosystem services in sub-Saharan Africa. A meta-analysis. *Agronomy for Sustainable Development*, 39, 47. <https://doi.org/10.1007/s13593-019-0589-8>
- Lasco, R. D., Delfino, R. J. P., & Espaldon, M. L. O. (2014). Agroforestry systems: Helping smallholders adapt to climate risks while mitigating climate change. *WIREs Climate Change*, 5(6), 825–833. <https://doi.org/10.1002/wcc.301>
- Leakey, R. R. B. (1999). Potential for novel food products from agroforestry trees: A review. *Food Chemistry*, 66(1), 1–14. [https://doi.org/10.1016/s0308-8146\(98\)00072-7](https://doi.org/10.1016/s0308-8146(98)00072-7)
- USDA National Agroforestry Center. (2021). *Marketing agroforestry products: Lessons from producers*. <https://www.fs.usda.gov/nac/assets/documents/morepublications/MarketingAgroforestryProducts-508.pdf>
- Martin, D. A., Osen, K., Grass, L., Hölscher, D., Tschantke, T., Wurz, A., & Kreft, H. (2020). Land-use history determines ecosystem services and conservation value in tropical agroforestry. *Conservation Letters*, 13(5), e12740. <https://doi.org/10.1111/conl.12740>
- Mercer, D. E. (2004). Adoption of agroforestry innovations in the tropics: A review. *Agroforestry Systems*, 61, 311–328. <https://doi.org/10.1023/b:agfo.0000029007.85754.70>
- Mukhlis, I., Rizaludin, M. S., & Hidayah, I. (2022). Understanding socio-economic and environmental impacts of agroforestry on rural communities. *Forests*, 13(4), 556. <https://doi.org/10.3390/f13040556>
- Munsell, J. F., Bukowski, C. J., Yanez, M., & Allen, J. A. (2021). Urban food forests and community agroforestry systems. In H. E. G. Garrett, S. Jose, & M. A. Gold (Eds.), *North American Agroforestry* (3rd ed., pp. 315–335). <https://doi.org/10.1002/9780891183785.ch10>
- Nair, P. K. R., Kumar, B. M., & Nair, V. D. (2021). *An introduction to agroforestry: Four decades of scientific developments*. Springer Cham. <https://doi.org/10.1007/978-3-030-75358-0>

- Ntawuruhunga, D., Ngowi, E. E., Mangi, H. O., Salanga, R. J., & Shikuku, K. M. (2023). Climate-smart agroforestry systems and practices: A systematic review of what works, what doesn't work, and why. *Forest Policy and Economics*, 150, 102937. <https://doi.org/10.1016/j.forpol.2023.102937>
- Pancholi, R., Yadav, R., Gupta, H., Vasure, N., Choudhary, S., Singh, M. N., & Rastogi, M. (2023). The role of agroforestry systems in enhancing climate resilience and sustainability- A review. *International Journal of Environment and Climate Change*, 13(11), 4342–4353. <https://doi.org/10.9734/ijec/2023/v13i113615>
- Pantera, A., Mosquera-Losada, M. R., Herzog, F., & den Herder, M. (2021). Agroforestry and the environment. *Agroforestry Systems*, 95, 767–774. <https://doi.org/10.1007/s10457-021-00640-8>
- Pattanayak, S. K., Mercer, D., Sills, E., & Cassingham, K. (2012). *Adopting agroforestry*. Semantic Scholar. <https://consensus.app/papers/adopting-agroforestry-pattanayak-mercerc/35c6488294fd5058b8cb9ad5fd491a9/>
- Proctor, K. W., Murthy, G. S., & Higgins, C. W. (2020). Agrivoltaics align with Green New Deal goals while supporting investment in the US' rural economy. *Sustainability*, 13(1), 137. <https://doi.org/10.3390/su13010137>
- Rodrigues Maia, F. (2023). The economic viability of an agroforestry system in relation to monoculture. *Journal of Interdisciplinary Debates*, 4(04), 341–356. <https://doi.org/10.51249/jid.v4i04.1744>
- Salve, A., Tiwari, C., & Baghele, L. (2022). Impact of agroforestry systems: A review. *Asian Journal of Microbiology, Biotechnology & Environmental Sciences*, 24(2), 214–223. <https://doi.org/10.53550/ajmbes.2022.v24i02.002>
- Santiago-Freijanes, J. J., Mosquera-Losada, M. R., Rois-Díaz, M., Ferreiro-Domínguez, N., Pantera, A., Aldrey, J. A., & Rigueiro-Rodríguez, A. (2021). Global and European policies to foster agricultural sustainability: Agroforestry. *Agroforestry Systems*, 95, 775–790. <https://doi.org/10.1007/s10457-018-0215-9>
- Santos, P. Z. F., Crouzeilles, R., & Sansevero, J. B. B. (2019). Can agroforestry systems enhance biodiversity and ecosystem service provision in agricultural landscapes? A meta-analysis for the Brazilian Atlantic Forest. *Forest Ecology and Management*, 433, 140–145. <https://doi.org/10.1016/j.foreco.2018.10.064>
- Schwartzman, G. (2023). *After coal: Power, development, and post-coal politics in Appalachia* (Publication Number. 30487045) [Doctor Dissertation, University of Minnesota]. ProQuest Dissertations & Theses Global. <https://conservancy.umn.edu/items/c256d94c-f7ed-43eb-a231-ad825d2c3cca>
- Singh, V., Johar, V., Kumar, R., & Chaudhary, M. (2021). Socio-economic and environmental assets sustainability by agroforestry systems: A review. *International Journal of Agriculture, Environment and Biotechnology*, 14(04), 521–533. <https://doi.org/10.30954/0974-1712.04.2021.6>
- Smith, K. E., Bandola-Gill, J., Meer, N., Stewart, E., & Watermeyer, R. (2020). Telling tales of impact: As seen through the eyes of user assessors. In *The impact agenda: Controversies, consequences and challenges* (pp. 183–194). Bristol University Press. <https://doi.org/10.51952/9781447339861.ch009>
- Smith, M. M., Bentrup, G., Kellerman, T., Macfarland, K., Straight, R., Ameyaw, L., & Stein, S. (2022). Silvopasture in the USA: A systematic review of natural resource professional and producer-reported benefits, challenges, and management activities. *Agriculture, Ecosystems & Environment*, 326, 107818. <https://doi.org/10.1016/j.agee.2021.107818>
- Udawatta, R. P., Garrett, H. E., Jose, S., & Lovell, S. T. (2021). Water quality and quantity benefits of agroforestry and processes: Long-term case studies from Missouri, USA. In R. P. Udawatta & S. Jose (Eds.), *Agroforestry and ecosystem services* (pp. 113–139). Springer Cham. https://doi.org/10.1007/978-3-030-80060-4_6
- Udawatta, R. P., Rankoth, L., & Jose, S. (2019). Agroforestry and biodiversity. *Sustainability*, 11(10), 2879. <https://doi.org/10.3390/su11102879>
- Udawatta, R. P., Rankoth, L., & Jose, S. (2021). Agroforestry for biodiversity conservation. In R. P. Udawatta & S. Jose (Eds.), *Agroforestry and ecosystem services*, (pp. 245–274). Springer Cham. https://doi.org/10.1007/978-3-030-80060-4_10
- Williams, M. R., Leatherwood, L., Byrd, L., Boyd, M. S., & Pennington, K. (2010). Alumni engaging students from Under-Served Groups in Southern Appalachia. *Community College Enterprise*, 16(1), 23–35. https://digitalcommons.odu.edu/efl_fac_pubs/32/
- Zabala, A., Pascual, U., García-Barrios, L. E., & Mukherjee, N. (2025). Drivers to adopt agroforestry and sustainable land-use innovations: A review and framework for policy. *Land Use Policy*, 151, 107468. <https://doi.org/10.1016/j.landusepol.2025.107468>
- Zawarus, P. W., & Ortega, L. (2022). Food desert to food oasis: An engagement with the community through evidence-based methods. *Creative Collaborations*. https://digitalscholarship.unlv.edu/cfa_collaborate/13/
- Zinkhan, F. C., & Mercer, D. E. (1996). An assessment of agroforestry systems in the southern USA. *Agroforestry Systems*, 35, 303–321. <https://doi.org/10.1007/BF00044460>
- Zipper, C. E., Burger, J. A., Barton, C. D., & Skousen, J. G. (2013). Rebuilding soils on mined land for native forests in Appalachia. *Soil Science Society of America Journal*, 77(2), 337–349. <https://doi.org/10.2136/sssaj2012.0335>
- Zomer, R. J., Bossio, D. A., Trabucco, A., van Noordwijk, M., & Xu, J. (2022). Global carbon sequestration potential of agroforestry and increased tree cover on agricultural land. *Circular Agricultural Systems*, 2, 3. <https://doi.org/10.48130/CAS-2022-0003>

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