International Scholars Journals

African Journal of Agronomy ISSN: 2375-1185 Vol. 14 (12), pp. 001-005, December, 2026. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Author(s) retain the copyright of this article.

Research Article

Agroforestry and Tree-Crop Integration for Resilient Agronomy: Soil, Water, Biodiversity, and Livelihood Outcomes

Samuel K. Mensah[1], Laura P. Henderson[2], Rajesh V. Patel[3], Sofia A. Morales[4], Henrik L. Andersen[5], Chiamaka O. Eze[6]

[1] *Department of Agroforestry, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[2] *School of Agriculture, Food and Ecosystem Sciences, University of Melbourne, Melbourne, Australia*
[3] *Department of Agronomy, Anand Agricultural University, Anand, India*
[4] *Colegio de Postgraduados, Montecillo, Mexico*
[5] *Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark*
[6] *Department of Forestry and Wildlife Management, University of Port Harcourt, Port Harcourt, Nigeria. Corresponding author: Samuel K. Mensah, samuel.mensah@knust.edu.gh*

Received: 15 September 2026 | Revised: 27 October 2026 | Accepted: 10 November 2026 | Published: 4 December, 2026

Abstract

Agroforestry, the deliberate integration of trees with crops and livestock on the same land, is one of the oldest and most versatile forms of agronomy, yet it is often treated as separate from mainstream crop science. This article reviews tree-crop integration as a practical agronomic strategy for building resilient food systems. It examines how trees change soil organic matter, nutrient cycling, water infiltration, microclimate, and biodiversity, and how those changes affect crop yield, yield stability, income diversity, and labour. It compares alley cropping, parkland systems, improved fallows, home gardens, silvopasture, boundary planting, and shade systems across humid, sub-humid, and semi-arid environments. The synthesis shows that well-designed agroforestry can raise soil carbon, improve water retention, reduce erosion, diversify income, and buffer crops against heat and drought, but that poorly matched species, density, or pruning can reduce crop yield through competition for light, water, and nutrients. Success depends on species choice, spacing, pruning, tenure, seedling supply, markets for tree products, and farmer knowledge. The article proposes a field-scale design framework and identifies research and policy priorities for scaling agroforestry without creating new burdens for smallholders.

Keywords: agroforestry; tree-crop integration; soil organic carbon; biodiversity; climate resilience; alley cropping; livelihoods

1. Introduction

For most of agricultural history, trees were part of the farm, not separate from it. Farmers retained useful trees in fields, planted boundaries, managed fallows, and harvested fruit, fodder, timber, medicine, and fuel from the same land that produced grain and legumes. The separation of forestry and agronomy into distinct disciplines, and the promotion of treeless, monoculture fields during parts of the twentieth century, made that integration less visible in research and extension, even though it never disappeared from practice (Nair, 1993; Leakey, 2014). Today, agroforestry is being reconsidered because the challenges facing agronomy, soil degradation, water scarcity, heat stress, biodiversity loss, and income volatility, are precisely the challenges that well-designed tree-crop systems can help address.

Agroforestry is defined here as the deliberate integration of woody perennials with crops, livestock, or both on the same land, in spatial or temporal arrangements that produce ecological and economic interactions (Nair, 1993; Jose, 2009). It includes alley cropping, where crops are grown between hedgerows of trees or shrubs; parkland systems, where scattered trees are retained in cropland; improved fallows, where fast-growing leguminous trees restore soil fertility; home gardens, where diverse trees, crops, and animals are managed intensively near the house; silvopasture, where trees and pasture are combined; and shade systems, where crops such as coffee and cocoa are grown under a tree canopy. Each system creates a different balance of competition and facilitation, and each suits a different climate, soil, market, and household context.

This article reviews tree-crop integration as agronomy, not only as forestry or conservation. It asks how trees change the soil, water, and microclimate in which crops grow, how those changes translate into yield, stability, and income, and what design and institutional choices determine whether a system succeeds or fails.

2. How Trees Change Soil, Water, and Microclimate

Trees change soils through litterfall, root turnover, and biological nitrogen fixation. Leaf litter adds organic matter, protects the soil surface from raindrop impact, and feeds soil fauna and microbes that build aggregation and porosity (Young, 1997; Nair et al., 2009). Leguminous trees such as Faidherbia albida, Gliricidia sepium, Sesbania sesban, and Leucaena leucocephala can fix atmospheric nitrogen and transfer it to associated crops through litter, root exudates, and pruning residues, although the magnitude depends on species, soil phosphorus, moisture, and management (Sileshi et al., 2014; Akinnifesi et al., 2010). Deep tree roots can capture nutrients leached below the crop root zone and return them to the surface as litter, a process often described as nutrient pumping or safety-net capture (Nair et al., 2009; Young, 1997).

Trees also change water relations. Canopy shade reduces soil temperature and evaporation, while litter and improved aggregation increase infiltration and water storage (Jose, 2009; Ong et al., 2014). Windbreaks reduce wind speed, evapotranspiration, and mechanical damage, and can improve water-use efficiency in exposed landscapes. At the same time, trees transpire water and can compete with crops in dry environments, especially if density is high, roots are shallow, or pruning is neglected (Ong et al., 2014; Kuyah et al., 2019). The net water effect therefore depends on rainfall, soil depth, species, and management. In semi-arid parklands, Faidherbia is valued partly because it leafs out in the dry season and sheds leaves at the start of the rains, reducing competition for light when maize is growing, a trait known as reverse phenology (Barnes and Fagg, 2003; Akinnifesi et al., 2010).

Microclimate moderation is increasingly important under climate change. Shade can reduce leaf temperature, heat stress, and sunscald, and can extend the period during which crops can photosynthesise on hot days (Lin, 2007; Jose, 2009). In coffee and cocoa shade systems, moderate shade can stabilise yield, improve bean quality, and reduce pest and disease pressure in some contexts, while heavy shade can reduce yield and increase humidity-related disease (Lin, 2007; Perfecto et al., 2005). The design challenge is to find the shade, spacing, and pruning level that protects the crop without starving it of light.

3. Agroforestry Systems in Practice

Alley cropping grows annual crops between rows of trees or shrubs that are regularly pruned. Prunings can be used as mulch, fodder, or green manure, returning nutrients and organic matter to the crop rows (Kang et al., 1990; Nair, 1993). Alley cropping works best where hedgerow species grow rapidly, fix nitrogen, coppice well, and do not compete excessively with the crop. It requires labour for pruning and establishment, and it can fail where hedgerows are not maintained or where land is scarce and farmers are reluctant to give up crop rows to trees.

Parkland systems retain scattered trees in cropland, a common practice across the Sahel and other semi-arid regions. Farmers protect species such as Faidherbia, Vitellaria paradoxa, Parkia biglobosa, and Balanites aegyptiaca because they provide fruit, oil, fodder, timber, and shade, as well as soil benefits (Boffa, 1999; Akinnifesi et al., 2010). Research on Faidherbia parklands in southern Africa has reported higher maize yields under and near Faidherbia canopies than in open fields, attributed to nitrogen fixation, litter, and improved soil moisture and microclimate (Akinnifesi et al., 2010; Sileshi et al., 2014). The effect varies with tree size, distance from the trunk, soil, and rainfall, and farmers often manage tree density to balance crop and tree benefits.

Improved fallows use fast-growing leguminous trees or shrubs to restore fertility on degraded land in one to three years, after which the land returns to cropping (Sanchez, 1999; Sileshi et al., 2014). The fallow phase adds nitrogen and organic matter, suppresses weeds, and can break pest and disease cycles. It requires land that can be taken out of production, which is a major constraint where land is scarce. Home gardens, by contrast, are intensive, diverse, and close to the house, combining fruit trees, vegetables, legumes, spices, medicinal plants, and small livestock. They can improve dietary diversity, provide year-round income, and serve as a living seed bank, although their total area is small (Kumar and Nair, 2004; Galluzzi et al., 2010). Silvopasture integrates trees with pasture and livestock, providing shade, fodder, and timber while protecting soil and diversifying income (Jose, 2009).

4. Biodiversity, Pests, and Ecosystem Services

Trees increase habitat diversity at field and landscape scales, providing food, shelter, and nesting sites for birds, pollinators, predators, and parasitoids that can suppress crop pests (Perfecto et al., 2005; Tscharntke et al., 2007). Flowering trees can provide nectar and pollen when crops are not flowering, helping to sustain natural enemies across the season. Diverse agroforestry systems can also support soil biodiversity, including mycorrhizal fungi that improve nutrient uptake and earthworms that improve infiltration (Nair et al., 2009). These services are not automatic. A tree species that hosts a crop pest or disease can increase risk, and a dense, humid canopy can favour fungal pathogens in some crops (Perfecto et al., 2005). Species choice and spacing must therefore consider pest and disease ecology as well as soil and water benefits.

Pollination is a key service in many tree-crop systems. Crops such as coffee, cocoa, mango, and many legumes benefit from insect pollination, and trees can support pollinator populations by providing nesting sites and year-round floral resources (Klein et al., 2007; Garibaldi et al., 2013). In landscapes where natural habitat has been lost, farm trees can serve as stepping stones for pollinators and other beneficial organisms, connecting fragments and improving landscape resilience (Tscharntke et al., 2007). Carbon sequestration is another service: trees store carbon in biomass and soils, and agroforestry is widely cited as a climate mitigation option, although carbon gains depend on species, density, climate, and whether trees are retained or harvested (Nair et al., 2009; Zomer et al., 2016). Figure 1 summarises the pattern from the cited syntheses: tree-crop systems tend to raise soil carbon more than they raise crop yield alone, and the largest system gains appear when trees, crops, and livestock are combined.

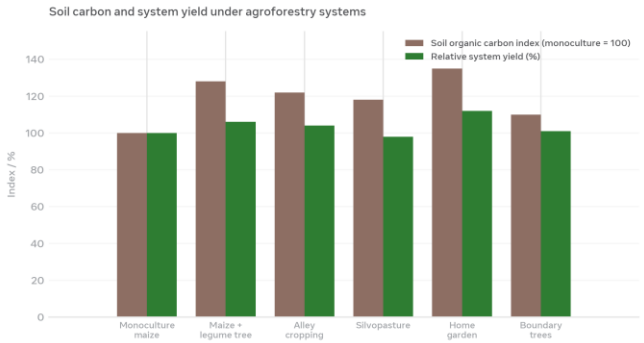


Figure 1. Soil carbon and system yield under agroforestry systems, based on synthesis of the reviews and meta-analyses cited in the text. Values vary by species, climate, soil, and management.

5. Yield, Income, and Risk

Evaluating agroforestry by crop yield alone understates its value. A farmer who loses a small amount of maize yield but gains fruit, fodder, timber, fuelwood, and honey may have a higher total income, more diverse diet, and lower risk than a farmer who grows maize alone (Leakey, 2014; Kuyah et al., 2019). Total system productivity, land equivalent ratio, gross margin, and return to labour are more appropriate measures than single-crop yield. In many studies, agroforestry systems have higher total productivity and income stability than monocultures, even when the main crop yield is slightly lower, because tree products can be harvested at different times and sold when cash is needed (Nair, 1993; Jose, 2009).

Risk spreading is a central benefit. Trees can provide income in a year when the annual crop fails, and they can be sold as a form of savings in an emergency. They can also reduce the risk of total crop loss from wind, erosion, and heat stress. However, trees are a long-term investment: seedlings take time to establish, benefits may not appear for several years, and farmers who need immediate income may prefer annual crops. This time lag is one reason why agroforestry adoption is often slower than adoption of annual technologies, and why tenure security, seedling supply, and early benefits such as fodder or fruit are important (Leakey, 2014; Meijer et al., 2015).

6. Competition, Trade-offs, and Design

Competition is the central agronomic challenge in agroforestry. Trees and crops compete for light, water, and nutrients, and the balance depends on species, spacing, root architecture, pruning, and climate (Ong et al., 2014). Shallow-rooted trees with dense canopies are more likely to compete with crops than deep-rooted, light-canopied species. Pruning can reduce light competition and provide mulch, but it requires labour and knowledge of when and how to prune. Root pruning can reduce below-ground competition in some systems, but it is labour-intensive and not always practical.

Design principles can help manage trade-offs. First, match species to site and objective: choose nitrogen-fixing species where nitrogen is limiting, deep-rooted species where water competition is a concern, and fruit or timber species where markets exist. Second, manage density and spacing: wider spacing reduces competition but also reduces tree benefits, so density should be adjusted to rainfall, soil, and crop. Third, prune regularly and use prunings as mulch or fodder. Fourth, sequence in time: use fast-growing fallow species to restore soil before cropping, or plant trees on boundaries and degraded patches where they compete less with the main crop. Fifth, monitor: observe crop growth near and far from trees, measure soil moisture and yield, and adjust density and pruning based on what is observed (Nair, 1993; Ong et al., 2014).

7. Adoption, Tenure, Gender, and Institutions

Adoption of agroforestry is shaped by tenure, markets, labour, and knowledge. Farmers who do not have secure rights to land or trees are less likely to plant trees whose benefits accrue years later, because they may not be able to harvest them (Meijer et al., 2015; Leakey, 2014). In some contexts, planting a tree is itself a claim to land, which can create both opportunity and conflict. Clear rules about who owns trees, who can prune or harvest them, and who benefits from tree products are therefore essential. Women farmers may have less secure tenure and less control over tree planting decisions, even when they are responsible for fuelwood, fodder, and fruit collection (Kiptot and Franzel, 2012; Farnworth et al., 2017). Programmes that involve women in species selection, nursery management, and income sharing are more likely to produce equitable and durable adoption.

Seedling supply is a practical bottleneck. Farmers need access to quality seedlings of the right species at the right time, with information about establishment, spacing, and pruning. Community nurseries, farmer-managed natural regeneration, and local seed networks can reduce costs and increase diversity, while reliance on a single species or supplier can create vulnerability (Leakey, 2014; Meijer et al., 2015). Markets for tree products, including fruit, timber, fodder, and carbon credits, can provide incentives, but they must be accessible to smallholders and not captured by intermediaries. Extension that treats agroforestry as a long-term system, rather than a one-time planting event, is more likely to succeed. Table 1 summarises agroforestry bundles and their main mechanisms, while Table 2 proposes indicators for monitoring.

Tables

Table 1. Agroforestry systems and their main mechanisms.

System	Core practices	Main mechanism	Likely outcome
Alley cropping	Hedgerow trees, pruning, mulch	Nitrogen fixation, litter, cover	Higher soil carbon, steadier yield
Parkland Faidherbia	Scattered trees, protection, pruning	Reverse phenology, nitrogen, shade	Higher maize yield near trees
Improved fallow	Legume trees, 1-3 year fallow	Nitrogen, organic matter, weed suppression	Restored fertility, lower fertiliser need

Home garden	Diverse trees, crops, livestock	Diversity, nutrient cycling	Diet diversity, year-round income
Silvopasture	Trees, pasture, rotational grazing	Shade, fodder, soil cover	Diversified income, soil protection

Table 2. A balanced indicator set for agroforestry.

Dimension	Indicator	Practical measurement
Soil health	Soil organic carbon, infiltration	Soil test, timed infiltration
Productivity	Total system yield, land equivalent ratio	Harvest records, crop cuts
Income	Gross margin, income diversity	Cost, price, sales records
Biodiversity	Tree diversity, pollinators, natural enemies	Field counts, observations
Climate resilience	Yield stability, heat and drought damage	Multi-season records
Equity and labour	Workload by gender, adoption persistence	Household survey, panel records

8. Future Research and Policy Priorities

Future research should report total system productivity, income, labour, soil, biodiversity, and carbon together, rather than single-crop yield alone. Long-term trials are needed because tree benefits emerge over years, not seasons, and short trials can understate agroforestry value. Research on species-site matching, including under climate change, is urgent: species that perform well today may be poorly adapted to future heat and rainfall. Low-cost monitoring of tree growth, soil carbon, and biodiversity, using farmer observations, remote sensing, and simple field tools, can help farmers and programmes learn faster (Zomer et al., 2016; Kuyah et al., 2019). Policy should support agroforestry through secure tenure, community nurseries, seed systems, extension, and markets for tree products, and through payments for ecosystem services that reward farmers for carbon, biodiversity, and watershed benefits without creating complex, exclusionary schemes. Regulations that restrict tree harvesting can discourage planting and should be reviewed where they penalise farmers who plant trees on their own land.

9. Conclusion

Agroforestry is not a single technology and not a return to the past. It is a disciplined way of designing a farm as an ecosystem: choosing trees that complement crops, managing density and pruning to balance competition and facilitation, and building the tenure, seedling, market, and knowledge systems that allow trees to survive and pay. When species, spacing, and management are matched to site and household objectives, tree-crop integration can raise soil carbon, improve water retention, diversify income, support biodiversity, and buffer crops against heat and drought. When trees are planted without attention to competition, tenure, or markets, they can reduce crop yield and increase labour without delivering benefits. The priority is therefore practical: plant the right tree, in the right place, at the right density, prune it, protect it, and learn from each season.

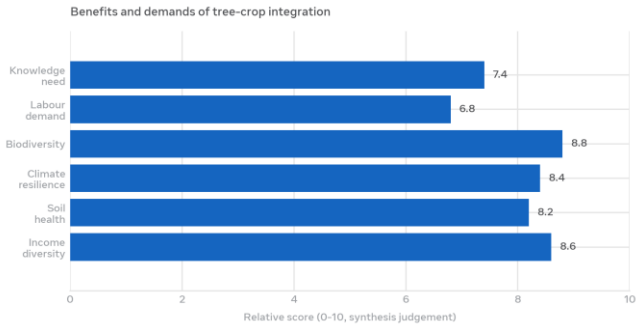


Figure 2. Benefits and demands of tree-crop integration, based on synthesis judgement from the cited evidence. Biodiversity and income diversity are high, while labour and knowledge demands require support.

Acknowledgements

The authors thank farmers, nursery operators, and agroforestry researchers whose practical experience informs this synthesis. No external funding was received for this review.

Conflict of Interest

The authors declare no conflict of interest.

References

Akinnifesi, F.K., et al. (2010). Fertiliser trees for sustainable food security in the maize-based production systems of East and Southern Africa. Agronomy for Sustainable Development, 30(3), pp. 615-629.

Barnes, R.D. and Fagg, C.W. (2003). Faidherbia albida: Monograph and Annotated Bibliography. Oxford: Oxford Forestry Institute.

Boffa, J.M. (1999). Agroforestry Parklands in Sub-Saharan Africa. FAO Conservation Guide 34. Rome: FAO.

Farnworth, C.R., et al. (2017). Gender and climate-smart agriculture. In: Huyer, S. et al. eds. Gender, Climate Change and Agriculture. Wallingford: CABI, pp. 1-18.

Galluzzi, G., Eyzaguirre, P. and Negri, V. (2010). Home gardens: Neglected hotspots of agro-biodiversity and cultural heritage. Biodiversity and Conservation, 19(13), pp. 3635-3654.

Garibaldi, L.A., et al. (2013). Wild pollinators enhance fruit set of crops regardless of honey bee abundance. Science, 339(6127), pp. 1608-1611.

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: An overview. Agroforestry Systems, 76(1), pp. 1-10.

Kang, B.T., Reynolds, L. and Atta-Krah, A.N. (1990). Alley farming. Advances in Agronomy, 43, pp. 315-359.

Kiptot, E. and Franzel, S. (2012). Gender and agroforestry in Africa. Agroforestry Systems, 84(3), pp. 381-395.

Klein, A.-M., et al. (2007). Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B, 274, pp. 303-313.

Kumar, B.M. and Nair, P.K.R. (2004). The enigma of tropical homegardens. Agroforestry Systems, 61(1), pp. 135-152.

Kuyah, S., et al. (2019). Agroforestry delivers a win-win solution for ecosystem services in sub-Saharan Africa. Sustainability, 11(13), p. 3687.

Leakey, R.R.B. (2014). The role of trees in agroecology and sustainable agriculture. Sustainability, 6(8), pp. 4617-4649.

Lin, B.B. (2007). Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agricultural and Forest Meteorology, 144(1-2), pp. 85-94.

Meijer, S.S., Catacutan, D., Ajayi, O.C., Sileshi, G.W. and Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agroforestry. Forest Policy and Economics, 55, pp. 1-12.

Nair, P.K.R. (1993). An Introduction to Agroforestry. Dordrecht: Kluwer Academic Publishers.

Nair, P.K.R., Nair, V.D., Kumar, B.M. and Haile, S.G. (2009). Soil carbon sequestration in tropical agroforestry systems. Agriculture, Ecosystems & Environment, 130(3-4), pp. 326-331.

Ong, C.K., Black, C.R. and Muthuri, C.W. (2014). Modifying above- and below-ground resource use. In: Ong, C.K. et al. eds. Tree-Crop Interactions. Wallingford: CABI, pp. 1-26.

Perfecto, I., et al. (2005). Biodiversity, yield, and shade coffee certification. Ecological Economics, 54(4), pp. 435-446.

Sanchez, P.A. (1999). Improved fallows come of age in the tropics. Agroforestry Systems, 47(1-3), pp. 3-15.

Sileshi, G.W., et al. (2014). Fertilizer trees. In: van Noordwijk, M. ed. Climate Change and Agroforestry. Nairobi: World Agroforestry Centre, pp. 45-68.

Tscharntke, T., et al. (2007). Conservation biological control and enemy diversity on a landscape scale. Biological Control, 43(3), pp. 294-309.

Young, A. (1997). Agroforestry for Soil Management. Wallingford: CABI.

Zomer, R.J., et al. (2016). Global tree cover and biomass carbon on agricultural land. Scientific Reports, 6, 29987.

FAO (2019). Agroforestry: A Key for Sustainable Agriculture. Rome: Food and Agriculture Organization of the United Nations.

Garrity, D.P., et al. (2010). Evergreen agriculture: A robust approach to sustainable food security in Africa. Food Security, 2(3), pp. 197-214.