CLIMATE SMART ACTIONS (CSA) AQUACULTURE, AGROFORESTRY AND RESOURCES MANAGEMENT

GLOBAL ISSUES & LOCAL PERSPECTIVES

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous **Climate smart actions (CSA) aquaculture, agroforestry and resources management** issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which **Climate smart actions (CSA) aquaculture, agroforestry and resources management** issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue **Climate smart actions (CSA) aquaculture, agroforestry and resources management** necessary in policy making process that will stimulate increase in food production and environmental sustainability. **Climate smart actions (CSA) aquaculture, agroforestry and resources management :** *Global Issues & Local Perspectives* is organized in three parts. Part One deals with The Concept of **Climate smart actions (CSA)**, Part Two is concerned with The Concept of **aquaculture,** and Part Three deals with the Concept of **agroforestry and resources management**

Eteyen Nyong; March 2026

Chapter 15:

Ecological Engineering in Agroforestry: Resource Management Approaches to Enhance Wildlife Services and Reduce Conflicts

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Chapter Outline **Pages**

1.0 Introduction

Agricultural expansion remains one of the most pervasive drivers of biodiversity loss, habitat fragmentation, and ecosystem service decline globally. In many tropical and subtropical regions, the conversion of forests into simplified monoculture systems has intensified human–wildlife interactions, often resulting in escalating human–wildlife conflict (HWC), declining agricultural sustainability, and erosion of rural livelihoods. Recent empirical evidence indicates that conventional agricultural intensification not only reduces wildlife populations but also undermines ecosystem functions such as pollination, biological pest regulation, and soil fertility, thereby increasing farmers' dependence on external inputs and heightening vulnerability to climate variability (Cappelli, Domeignoz-Horta, Loaiza and Laine, 2022; DeFries, Parashar, Neelakantan, Clark and Krishnaswamy, 2023). These challenges underscore the urgent need for land-use systems that simultaneously support food production, biodiversity conservation, and social resilience.

Agroforestry systems, defined as the deliberate integration of trees with crops, livestock, or both have emerged as a critical interface between conservation and production landscapes. Unlike monocultural farming systems, agroforestry creates vertically and horizontally heterogeneous habitats that resemble key structural and functional attributes of natural ecosystems. This complexity enables agroforestry systems to support diverse wildlife assemblages while sustaining agricultural productivity (Jiang, Xiong, Xiao, Yang, Huang and Wu, 2023). However, despite growing recognition of agroforestry's ecological potential, many existing systems remain opportunistic rather than intentionally designed to optimize wildlife services or minimize conflict risks. This design gap limits the full realization of agroforestry as a tool for biodiversity conservation and conflict mitigation.

Ecological engineering offers a robust conceptual and practical framework for addressing this gap. Rooted in the intentional manipulation of ecological processes rather than reliance on external inputs, ecological engineering emphasizes system self-regulation, resilience, and multifunctionality (Wang, Wang, Wang, Burkhard, Che, Dai and Zheng, 2022). When applied to agroforestry landscapes, ecological engineering enables the deliberate configuration of vegetation structure, species composition, and spatial arrangement to enhance wildlife-derived ecosystem services such as pollination, biological pest control, and seed dispersal. Empirical studies across tropical and temperate regions demonstrate that structurally complex agroforestry systems support higher abundances of pollinators, insectivorous birds, and bats than conventional agricultural systems, leading to measurable improvements in crop yields and pest suppression (Abrahão, Santos-Ferreira, Garcia, Torezan-Silingardi, 2025; Jena, Jena, Deori, Kumar, Pradhan, Gautam and Paul, 2025).

At the same time, agroforestry landscapes frequently overlap with wildlife movement corridors and edge habitats surrounding protected areas, placing them at the frontline of human–wildlife interactions. Crop raiding, livestock predation, and property damage remain persistent challenges, particularly in regions where agricultural lands directly abut conservation areas. Recent research suggests that poorly planned agroforestry interventions may inadvertently attract wildlife without providing adequate conflict mitigation measures, thereby exacerbating tensions between conservation objectives and local livelihoods (Rosati, Borek and Canali, 2020). Conversely, empirically grounded agroforestry designs such as deterrent hedges, spatial crop zonation, and habitat corridors have been shown to reduce conflict incidence while maintaining biodiversity benefits (Kumar, Prakash, and Patel, 2023; Tantipisanuh *et al*., 2024).

Against this backdrop, the central problem addressed in this chapter is the lack of integrated, empirically informed frameworks that link ecological engineering principles with agroforestry design for the dual goals of enhancing wildlife services and reducing human–wildlife conflict. While substantial empirical evidence supports the ecological benefits of agroforestry, fewer studies explicitly connect system design features to conflict mitigation outcomes and governance mechanisms at landscape scales. This disconnect hampers the translation of scientific insights into scalable, policy-relevant interventions, particularly in developing regions where land-use pressures and livelihood vulnerabilities are most acute (Kpoviwanou, Sourou, and Christine, 2024).

This chapter therefore synthesizes ecological theory, empirical research, and applied case studies to examine how agroforestry systems can be deliberately engineered to function as wildlife-supporting, conflict-sensitive landscapes. Drawing on global evidence from Africa, Asia, and Latin America, it explores how structural, spatial, and functional engineering approaches influence wildlife services, ecosystem resilience, and human–wildlife coexistence. By integrating ecological, socioeconomic, and governance dimensions, the chapter advances an interdisciplinary framework for positioning agroforestry as a scalable, adaptive solution to biodiversity loss, ecosystem degradation, and conflict-prone agricultural frontiers under accelerating global change.

1.1 Bridging Theory and Practice: Linking Ecological Engineering to Empirical Case Evidence

Despite the growing body of empirical evidence demonstrating the ecological benefits of agroforestry, a persistent gap remains between theory-driven system design and its practical application in conflict-prone agricultural landscapes. Many agroforestry initiatives prioritize productivity or tree cover expansion without explicitly integrating wildlife movement ecology, conflict risk mapping, or community governance mechanisms. This disconnects often results in systems that either underperform in delivering wildlife services or inadvertently intensify human–wildlife conflict. The case studies presented in this chapter are therefore selected to address this central problem by illustrating how ecological engineering principles, when combined with spatial planning, participatory governance, and adaptive management, can translate theory into practice across diverse socioecological contexts.

Specifically, the Southeast Asian corridor case demonstrates how landscape-scale spatial engineering can reduce megafauna conflict while restoring connectivity; the Latin American silvopastoral case illustrates how structural and functional engineering enhances wildlife services without compromising livestock productivity; and the East African national strategy highlights how governance and policy coherence are essential for scaling agroforestry-based conflict mitigation. Together, these cases provide comparative evidence that agroforestry systems must be intentionally engineered and institutionally supported to achieve simultaneous gains in biodiversity conservation, ecosystem services, and human–wildlife coexistence.

2.0 Ecological Foundations of Wildlife-Supporting Agroforestry

2.1 Habitat Complexity and Niche Diversification

Agroforestry systems provide greater structural and compositional diversity than monocultures, generating multiple microhabitats and ecological niches (Jiang *et al*., 2023). Vertical layering from groundcover to understory shrubs, mid-canopy fruit trees, and emergent shade trees supports a wide array of taxa, including pollinators, insectivorous birds, frugivorous mammals, amphibians, and reptiles (Diaz-Chaux, Velasquez-Valencia, Martinez-Salinas and Casanoves, 2025; Richard and Marja, 2025). This complexity underpins wildlife services and enhances ecological resilience.

2.2 Trophic Interactions and Pest Regulation

Trophic interactions are central to pest regulation in agroforestry systems, where diverse assemblages of predatory arthropods, insectivorous birds, and bats contribute to the suppression of agricultural pests (Wang and Shaner, 2025). Trees embedded within cropping or grazing areas provide essential refuges, nesting sites, and structurally complex foraging substrates that sustain these natural enemies throughout seasonal cycles. Mixed-species agroforestry systems increase food web complexity by supporting multiple trophic pathways and alternative prey resources, thereby enhancing the resilience and stability of pest control functions. As a result, reliance on synthetic pesticides is reduced, promoting both ecological sustainability and long-term agricultural productivity (Cappelli *et al*., 2022).

2.3 Connectivity and Movement Ecology

Habitat fragmentation represents one of the most significant threats to wildlife persistence in human-dominated landscapes. Agroforestry systems can mitigate fragmentation by strategically integrating trees to form corridors and stepping-stone habitats that connect remnant forests, riparian buffers, and protected areas (DeFries *et al*., 2023). These structurally continuous or semi-continuous elements facilitate animal movement across agricultural matrices, reducing isolation and mortality risks. Enhanced connectivity promotes genetic exchange, supports dispersal processes, and increases population resilience to environmental disturbance. Importantly, connected agroforestry landscapes also improve species' capacity to track climate-driven shifts in suitable habitat, thereby strengthening long-term adaptive potential under changing climatic conditions (Oloo, 2025).

3.0 Ecological Engineering Approaches in Agroforestry Systems

Ecological engineering in agroforestry entails the deliberate configuration of biological and physical components to enhance ecosystem services while sustaining productivity. By integrating trees, crops, and livestock, practitioners manipulate structural complexity, spatial arrangement, and functional interactions. Such designs regulate nutrient cycling, microclimate, biodiversity, and resilience, transforming managed landscapes into multifunctional systems that align agronomic objectives with long-term ecological stability across diverse socioecological contexts globally and scales.

3.1 Structural Engineering: Manipulating Vegetation Architecture

Structural engineering in agroforestry focuses on intentional manipulation of vegetation architecture to enhance ecological functionality. Practices such as promoting vertical canopy stratification, conserving diverse understory layers, and retaining standing or fallen deadwood increase habitat heterogeneity and resource availability. The deliberate preservation of cavity-bearing trees is particularly significant, as these structures support bats and cavity-nesting birds that contribute essential ecosystem services, including pollination and natural pest regulation, thereby reinforcing system resilience and ecological self-regulation (Nugroho, Mardiastuti, Mulyani and Rahman, 2023; Sandoval, Rojas, Retana, Guttirez and Barrantes, 2022).

3.2 Spatial Engineering: Landscape-Scale Design

Spatial engineering in agroforestry emphasizes landscape-scale design strategies that coordinate the placement of trees, hedgerows, riparian buffers, and woodlots to enhance ecological connectivity and functional flows. By strategically configuring these elements, practitioners facilitate species movement, gene flow, and the dispersal of ecosystem services across fragmented agricultural landscapes. Advanced spatial planning tools, including least-cost path analysis, circuit theory models, and GIS-based corridor mapping, are increasingly employed to identify priority areas for intervention. Such approaches strengthen habitat networks, reduce ecological isolation, and improve the adaptive capacity of agroforestry systems under changing environmental conditions (Tantipisanuh, Phakpian, Tangtorwongsakul, Vinitpornsawan and Ngoprasert, 2024).

3.3 Functional Engineering: Designing for Ecosystem Services

Functional engineering in agroforestry prioritizes the intentional design of biological interactions to optimize ecosystem service provision. Through strategic species selection and spatial configuration, systems are engineered to enhance key processes such as pollination, nutrient cycling, and biological pest regulation. The incorporation of nitrogen-fixing trees improves soil fertility, while fruiting species and flowering shrubs provide continuous resources for pollinators and other beneficial organisms. By aligning species traits with desired ecological functions, agroforestry systems achieve synergistic gains in productivity, sustainability, and ecological integrity across temporal and spatial scales (Nair, 2021).

4.0 Enhancing Wildlife Services through System Design

4.1 Designing for Pollinators

Designing agroforestry systems for pollinators involves creating structurally and temporally diverse habitats that ensure the continuous availability of floral resources throughout the year. The integration of flower-rich understory plants, alongside tree and shrub species with staggered flowering phenologies, mitigates seasonal resource gaps that often constrain pollinator populations in simplified agricultural landscapes. Such diversified designs support a wide range of pollinators, including bees, birds, and bats, enhancing pollination stability and crop yields while reinforcing broader biodiversity conservation objectives within productive agroecosystems (Katumo, Liang, Ochola, Lv, Wang and Yang, 2022).

4.2 Enhancing Biological Control

Enhancing biological control within agroforestry systems relies on the deliberate incorporation of plant species that supply nectar, shelter, and alternative prey for natural enemies of agricultural pests. Such functional plant diversity sustains predators and parasitoids during periods of low pest availability, stabilizing their populations. Silvopastoral and multistrata agroforestry systems, characterized by structural complexity and continuous resource provision, frequently support high abundances of predatory insects, birds, and arthropods. These conditions reduce pest outbreaks, lower dependence on chemical inputs, and contribute to resilient, self-regulating agroecosystems across varied production contexts (Han, Lipeizhong, Liang, Cai, Liu, Dou, Lu, Zhang, Wang and Su, 2024).

4.3 Supporting Seed Dispersal and Regeneration

Supporting seed dispersal and natural regeneration in agroforestry systems depends on fostering mutualistic interactions with birds and mammals that act as primary dispersal agents for many tree species. System designs that incorporate fruit-bearing trees, artificial or natural perches, and connected riparian buffers attract mobile fauna and facilitate seed movement across the landscape. These features promote colonization of suitable microsites, enhance genetic exchange, and accelerate successional dynamics. By leveraging animal-driven seed dispersal, agroforestry systems lessen the need for active replanting while enhancing long-term ecological resilience and maintaining structural continuity (Estrada-Villegas, Stevenson, López, DeWalt, Comita and Dent).

Comparative empirical studies consistently demonstrate that wildlife services in agroforestry systems are strongly contingent on design intensity and ecological intentionality. Meta-analyses from tropical and subtropical systems reveal that multistrata agroforestry supports significantly higher pollinator richness and visitation rates than both monocultures and low-diversity tree–crop systems (Katumo *et al*., 2022). Similarly, empirical evidence from Latin America and Southeast Asia indicates that pest suppression services increase with vertical complexity and continuous resource availability, particularly where trees provide permanent refugia for natural enemies (Sánchez, Jones, Purvis, Estrada-Carmona and De Palma, 2022; Han *et al*., 2024; Jena *et al*., 2025). These findings align with functional engineering theory, which emphasizes trait-based species selection and temporal resource continuity as prerequisites for stable ecosystem service provision.

However, cross-site comparisons also highlight trade-offs. Systems optimized solely for pollinators may not deliver equivalent gains in pest regulation or seed dispersal unless complementary structural elements are incorporated. This underscores the need for multifunctional system design that integrates multiple wildlife services rather than maximizing single outcomes, reinforcing the ecological engineering premise of coupled co-beneficial functions.

5.0 Reducing Human–Wildlife Conflict in Agroforestry Landscapes

5.1 Nature-Based Deterrence and System Redesign

Nature-based deterrence in agroforestry applies ecological engineering principles to reduce human–wildlife conflict through system redesign rather than lethal control. The strategic use of vegetative buffers, spatial crop zonation, and species-specific deterrent hedges alters wildlife movement patterns and foraging behavior. Such landscape features create physical and sensory barriers while maintaining habitat value, thereby discouraging crop raiding without undermining biodiversity. By aligning farm design with wildlife ecology, these approaches promote coexistence, enhance system sustainability, and support ethical, long-term conflict mitigation strategies (Hill, 2021).

5.2 Community-Based Monitoring and Early Warning Systems

Community-based monitoring and early warning systems strengthen human–wildlife coexistence by integrating local knowledge with ecological technologies. Participatory approaches employing camera traps, acoustic sensors, and mobile-based alert platforms enable timely detection of wildlife presence and movement. Such systems enhance situational awareness, support rapid response, and foster collective responsibility among stakeholders. By empowering communities to actively monitor landscapes and share real-time information, these initiatives reduce conflict risk, build trust in conservation interventions, and improve the long-term effectiveness of agroforestry-based mitigation strategies (Timis-Gansac, Dinca, Tudose, Constandache, Murariu, Cheregi, Moțiu and Derecichei, 2025).

5.3 Integrated Livestock Protection

Integrated livestock protection in silvopastoral systems combines behavioral, structural, and ecological strategies to reduce predation risk. The use of guardian animals enhances active deterrence, while reinforced night enclosures provide secure resting spaces during periods of heightened vulnerability. Strategic tree placement further improves visibility and disrupts predator concealment pathways without compromising forage availability. Together, these complementary measures align livestock management with landscape design, minimizing losses while supporting animal welfare, ecological integrity, and coexistence between pastoral livelihoods and wildlife in multifunctional agroforestry systems (Bommel *et al.*, 2024; Neupane *et al.*, 2025).

Empirical comparisons across Africa and Asia reveal that agroforestry-based conflict mitigation is most effective when ecological design is combined with behavioral and spatial interventions. Studies on deterrent hedges and crop zoning demonstrate significant reductions in crop-raiding incidents when buffer species are selected based on wildlife sensory ecology and movement behavior (Sitati, Walpole and Leader-Williams, 2025). Similarly, landscape-scale corridor planning in Southeast Asia shows that redirecting wildlife movement through agroforestry matrices reduces conflict frequency more effectively than reactive, farm-level deterrents alone (Tantipisanuh *et al.*, 2024).

Conversely, evidence also indicates that poorly planned agroforestry systems may act as attractants for wildlife if high-value crops or fruiting trees are placed near settlement boundaries without complementary deterrent measures (Rosati *et al.*, 2020). This comparative insight reinforces the chapter's central argument that agroforestry must be engineered with explicit conflict sensitivity. Successful systems integrate ecological knowledge, spatial planning, and community engagement, transforming agroforestry from a passive land-use option into an active coexistence strategy.

6.0 Socioeconomic and Governance Dimensions

6.1 Tenure Security and Incentive Structures

The long-term viability of wildlife-friendly agroforestry systems is closely linked to secure land tenure, which provides landholders with the confidence to invest in sustainable practices. Equally critical are well-defined benefit-sharing mechanisms that ensure equitable distribution of ecological and economic gains among local communities. Financial incentives, including Payments for Ecosystem Services (PES), further reinforce conservation-oriented behaviors by aligning individual interests with broader environmental objectives. Together, these governance and economic instruments create a synergistic framework that promotes both biodiversity conservation and resilient rural livelihoods (FAO, 2021).

6.2. Co-Management and Community Participation

Effective wildlife-friendly agroforestry relies not only on ecological strategies but also on inclusive governance frameworks that actively involve local communities. Integrating traditional ecological knowledge with formal management practices enhances the cultural relevance and practical feasibility of interventions, fostering greater acceptance among stakeholders. Participatory decision-making processes, supported by local governance structures, empower communities to take ownership of natural resource management, thereby promoting sustained stewardship. Such co-management approaches create mutually reinforcing relationships between ecological sustainability and social equity, ensuring that conservation objectives are aligned with local needs and priorities (CIFOR-ICRAF, 2023).

Cross-regional empirical studies consistently show that ecological performance alone is insufficient to ensure the persistence of wildlife-friendly agroforestry systems. Secure land tenure and incentive mechanisms emerge as decisive factors influencing adoption and long-term maintenance (FAO, 2021; Kpoviwanou *et al*., 2024). Comparative analyses from East Africa and Latin America indicate that Payment for Ecosystem Services schemes are most effective when embedded within participatory governance frameworks rather than implemented as stand-alone financial incentives.

Furthermore, co-management approaches that integrate traditional ecological knowledge with formal planning processes demonstrate higher levels of compliance, monitoring effectiveness, and conflict tolerance among farming communities (CIFOR-ICRAF, 2023; Timis-Gansac *et al*., 2025). These findings suggest that agroforestry-based ecological engineering operates within a coupled human–natural system, where social legitimacy and institutional alignment are as critical as biophysical design for achieving conservation and conflict mitigation outcomes at scale.

7. Methods, Tools, and Indicators for Adaptive Management

Adaptive management in this chapter is operationalized through a structured suite of methods, tools, and indicators that together enable iterative learning and evidence-based decision-making. Indicators span multiple ecological and social dimensions. Community-level responses to management interventions are reflected in biodiversity indicators such as species richness, abundance, and functional diversity. Habitat condition is assessed through canopy cover, patch size, and landscape connectivity indices, which reflect structural integrity and ecological processes. Wildlife service metrics, such as pollination and predation rates, link biodiversity patterns to ecosystem functioning. Complementing these, socioeconomic indicators including household income, stakeholder perceptions, and human–wildlife conflict incidence evaluate social outcomes and trade-offs. Monitoring integrates camera trapping, acoustic sensors, vegetation surveys, participatory mapping, drones, machine learning (ML) algorithms, bio-loggers and remote sensing to ensure spatially explicit, scalable, and stakeholder-informed assessments (Stephenson, Londono-Murcia, Borges, Claassens, Frisch-Nwakanma, Ling, McMullan-Fisher, Meeuwig, Unter, Walls, Burfield, Correa, Geller, Paredes, Mubalama, Ntiamoa-Baidu, Roesler, Rovero, Sharma, Wiwardhana, Yang and Fumagalli, 2022).

8.0 Case Studies

8.1. Case Study 1: Agroforestry Corridors in Southeast Asia

Case Study 1 examines agroforestry corridors in Southeast Asia as a landscape-based conservation strategy that aligns biodiversity objectives with rural livelihoods. Spatial connectivity mapping was combined with farmer-led agroforestry expansion to strategically restore habitat linkages across fragmented agricultural matrices. This integrated approach reduced human–elephant conflict by redirecting elephant movement away from high-risk areas while simultaneously enhancing dispersal opportunities for multiple taxonomic groups. The case illustrates how participatory land-use planning and ecological modeling can jointly deliver conservation, conflict mitigation, and livelihood co-benefits (Tantipisanuh *et al.*, 2024).

8.2. Case Study 2: Silvopastoral Systems in Latin America

Case Study 2 highlights silvopastoral systems in Latin America as multifunctional landscapes that integrate livestock production with biodiversity conservation. The strategic retention of native shade trees within pastures enhanced habitat heterogeneity, supporting insectivorous bird communities that contribute to natural pest regulation. Improved bird-mediated pest control reduced reliance on chemical inputs, while shaded conditions moderated microclimates and improved animal welfare, leading to increased dairy yields. This case demonstrates how ecologically informed farm design can generate synergistic gains for productivity, ecosystem services, and biodiversity (Sánchez *et al.*, 2022).

8.3. Case Study 3: National Agroforestry Strategy in East Africa

Case Study 3 examines the National Agroforestry Strategy in East Africa as an example of policy-driven integration of conservation and development objectives. By promoting wildlife-friendly agroforestry practices at a national scale, the strategy enhanced ecosystem services such as soil fertility, climate regulation, and habitat provision. Importantly, human–wildlife conflict mitigation was embedded within policy frameworks, aligning land-use planning, extension services, and conservation goals. This case illustrates how institutional coordination and policy coherence can scale localized agroforestry benefits into sustained, landscape-level outcomes (The United Republic of Tanzania, 2024).

9. Research Gaps and Future Directions

Despite increasing empirical support for agroforestry as a multifunctional land-use system, the comparative evidence synthesized in this chapter reveals several critical research gaps that constrain both scientific advancement and practical application. First, while numerous studies document positive associations between agroforestry complexity and wildlife services, most empirical investigations remain short-term and taxon-specific. There is a notable lack of longitudinal, multi-taxa studies capable of capturing delayed ecological responses, cumulative effects, and threshold dynamics that emerge over extended management cycles. Such temporal limitations obscure understanding of system resilience, service stability, and long-term conflict trajectories.

Second, comparative analyses highlight persistent methodological challenges in quantifying trade-offs and synergies between agricultural productivity, wildlife services, and conflict mitigation. Although evidence from silvopastoral and multistrata systems suggests that biodiversity gains can coincide with stable or improved yields, robust, standardized metrics for evaluating these interactions across ecological and socioeconomic gradients remain underdeveloped. This gap limits the ability of practitioners and policymakers to make evidence-based decisions under competing land-use objectives.

Third, the role of agroforestry in conserving genetic diversity within working landscapes remains poorly understood. While animal-mediated seed dispersal and habitat connectivity are increasingly documented, few studies explicitly assess genetic exchange, population viability, or the conservation of wild relatives of crops and livestock within agroforestry matrices. Addressing this gap is particularly urgent in the context of climate change, where genetic diversity underpins adaptive capacity.

Fourth, empirical comparisons across regions consistently indicate that social and institutional variables strongly mediate ecological outcomes, yet social and behavioral dimensions remain underrepresented in agroforestry research. Adoption barriers related to land tenure insecurity, labor demands, perceived risk, and uneven benefit distribution continue to limit scaling, especially in smallholder-dominated landscapes. Greater integration of social science methods including behavioral economics, political ecology, and participatory action research is needed to understand how governance structures and power relations shape agroforestry performance.

Finally, while landscape-scale planning and community-based monitoring show strong promise for reducing human–wildlife conflict, empirical evaluations of these approaches remain geographically uneven and context-specific. Future research should prioritize comparative, cross-regional studies that assess how combinations of ecological engineering, spatial planning, and governance mechanisms interact to influence conflict outcomes under diverse ecological and cultural settings (Kpoviwanou *et al*., 2024).

Addressing these gaps will require interdisciplinary, multi-scalar research frameworks that integrate ecology, agronomy, social science, and policy analysis. Such efforts are essential for advancing agroforestry from a promising land-use option to a scientifically grounded, scalable strategy for biodiversity conservation, ecosystem service provision, and human–wildlife coexistence.

10. Conclusions and Recommendations

Agroforestry represents a critical convergence point between biodiversity conservation and agricultural production, offering one of the most viable pathways for reconciling ecological sustainability with human well-being in multifunctional landscapes. This chapter demonstrates that when agroforestry systems are intentionally designed through ecological engineering principles, they transcend their traditional role as diversified farming systems and function instead as dynamic socioecological infrastructures. By manipulating structural complexity, spatial configuration, and functional interactions, engineered agroforestry systems enhance habitat quality, reinforce ecological processes, and deliver wildlife-derived ecosystem services, including pollination, biological pest regulation, and seed dispersal, while maintaining or improving agricultural productivity.

Crucially, the synthesis of empirical evidence and comparative case studies shows that agroforestry can also serve as an effective mechanism for reducing human–wildlife conflict when system design is explicitly aligned with species movement ecology and conflict risk dynamics. Nature-based deterrents, spatial zoning, ecological corridors, and community-based monitoring are most effective when embedded within agroforestry landscapes that anticipate wildlife behavior rather than react to conflict after it occurs. These findings underscore the necessity of shifting from reactive, species-specific conflict responses toward proactive, landscape-scale coexistence strategies.

To fully realize this potential, future research must move beyond isolated plot-level studies and prioritize integrative, landscape-scale analyses that capture ecological, socioeconomic, and governance interactions over time. Policy frameworks should explicitly embed agroforestry within national biodiversity strategies, land-use planning instruments, and climate adaptation agendas, ensuring coordination across agricultural, environmental, and development sectors. Equally essential is the institutionalization of community-led monitoring and adaptive management frameworks that combine local knowledge with ecological data, enabling context-specific learning, accountability, and long-term system resilience.

In sum, agroforestry when guided by ecological engineering and supported by inclusive governance, offers a scalable, science-based solution to biodiversity loss, ecosystem service degradation, and escalating human–wildlife conflict. Its strategic integration into landscape planning and policy regimes is therefore not optional but imperative for advancing sustainable development in increasingly human-dominated ecosystems.

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