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# Regenerative Transitions in Agroforestry Ecosystems: Evidence from Local Case Studies, Carbon Dynamics, and Livelihood Outcome

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Regenerative agriculture has emerged as a critical response to soil degradation, climate variability, and declining farm resilience, with agroforestry increasingly recognized as a core regenerative transition pathway. This paper synthesizes empirical evidence and real-world case studies to examine how agroforestry systems contribute to ecological restoration, carbon sequestration, biodiversity conservation, and livelihood enhancement. Using a mixed-method review approach, we integrate findings from global meta-analyses, national programs, and locally documented agroforestry interventions such as the Wadi model in India and traditional home garden systems in Kerala. Results indicate that agroforestry systems demonstrate significantly higher soil organic carbon accumulation, above ground biomass carbon storage, and income diversification compared to monoculture systems. Representative carbon sequestration rates ranged from 2.23–4.38 t. C ha.$^{-1}$ yr.$^{-1}$ in soils and up to 11.29 t. C ha.$^{-1}$ yr.$^{-1}$ in above ground biomass. Local case evidence further confirms improvements in household income stability, food security, and ecosystem resilience. The study concludes that agroforestry-led regenerative transitions offer scalable, locally adaptable solutions for climate-smart and inclusive agricultural development.

**Keywords:** Agroforestry; Regenerative agriculture; Carbon sequestration; Climate resilience; Livelihood diversification; Wadi model; Homegardens

## Introduction

Agricultural systems worldwide are facing unprecedented pressure from land degradation, biodiversity loss, and climate change, with nearly one-third of global agricultural land already degraded (FAO, 2017). Conventional mono cropping systems have contributed to declining soil organic matter, increased vulnerability to climate extremes, and reduced ecological resilience (Pretty et al., 2018). In response, regenerative agriculture has gained prominence as a systems-based approach aimed at restoring soil health, enhancing ecosystem services, and strengthening farm resilience (Rhodes, 2017).

Agroforestry defined as the deliberate integration of trees with crops and/or livestock on the same land management unit has been identified as a foundational practice within regenerative agriculture frameworks (Nair, 2011). By combining perennial woody components with annual production systems, agroforestry creates multifunctional landscapes that deliver ecological, economic, and social benefits simultaneously (Altieri et al., 2015).

In India and other tropical regions, agroforestry systems such as homegardens, silvopastoral systems, and agri-horti-forestry models have long been practiced as Indigenous and community-based land-use strategies (Kumar & Nair, 2004). However, their role in structured regenerative transitions particularly in terms of carbon sequestration and livelihood resilience requires systematic synthesis. This paper aims to bridge that gap by integrating scientific evidence with locally documented case studies.

## Review of Literature

Agroforestry systems have consistently been shown to improve soil organic carbon and nutrient cycling compared to conventional agriculture (Nair et al., 2009). A global meta-analysis by Feliciano et al. (2018) demonstrated that silvopastoral systems recorded mean soil carbon sequestration rates of 4.38 t C $ha^{-1}$ $yr^{-1}$, while improved fallow systems accumulated up to 11.29 t C $ha^{-1}$ $yr^{-1}$ in above ground biomass.

Altieri et al. (2015) reported that diversified agroecological systems, including agroforestry, significantly buffer climate variability by improving microclimates and water retention. Similarly, Pretty et al. (2018) emphasized that regenerative practices incorporating trees lead to sustained yield stability and ecosystem service enhancement.

In the Indian context, Kumar and Nair (2004) documented the exceptional biodiversity and productivity of Kerala home garden systems, highlighting their role in household nutrition and income security. BAIF Development Research Foundation (2019) reported that the Wadi agri-horti-forestry model increased annual household income by 2 to 3 times among tribal farmers while simultaneously restoring degraded lands.

FAO (2017) and IPCC (2019) have both recognized agroforestry as a cost-effective climate mitigation strategy due to its dual role in adaptation and carbon sequestration.

## Materials and Methods

**Review Design:** A narrative-cum-systematic review approach was adopted to synthesize peer-reviewed literature, institutional reports, and documented case studies on agroforestry-based regenerative transitions, from Peer-reviewed journals (Science of the Total Environment, Agriculture, Ecosystems & Environment, Agroforestry Systems) FAO, IPCC, and CIFOR-ICRAF reports, National and NGO documentation (e.g., BAIF Development Research Foundation) and Empirical studies on carbon sequestration in agroforestry systems

## Results

**Carbon Sequestration Performance:** Agroforestry systems exhibited substantial carbon sequestration potential across both soil and biomass pools. As illustrated in **Figure 1**, improved fallow and silvo-pastoral systems recorded the highest carbon accumulation, while tropical agroforestry systems showed consistent medium-range sequestration values.

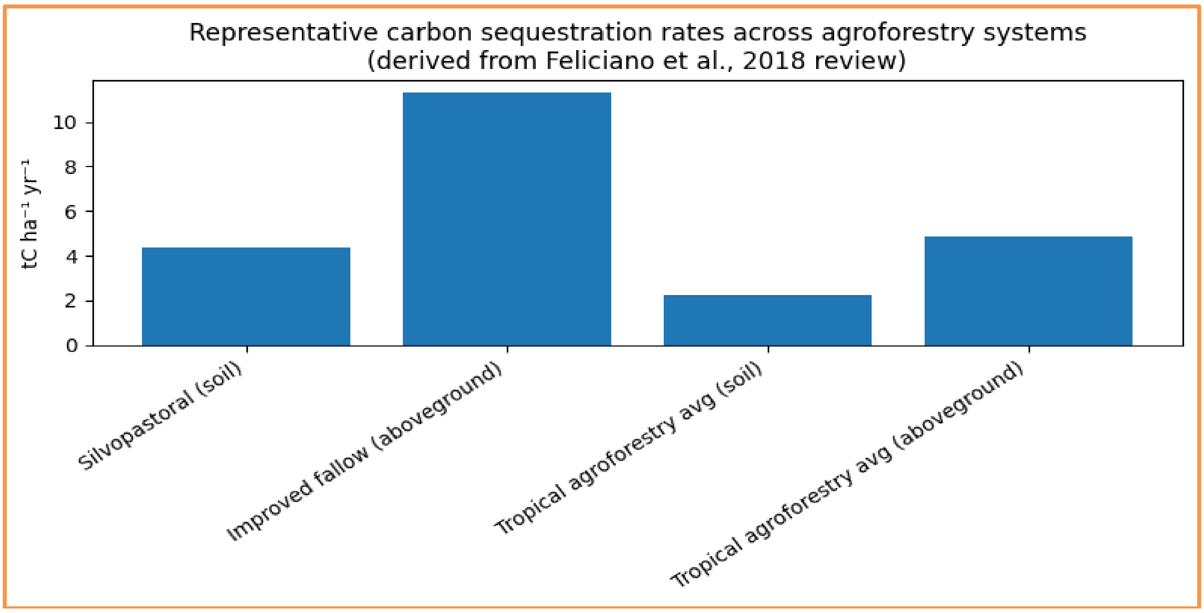


**Figure 1. Representative carbon sequestration rates (t C $ha^{-1}$ $yr^{-1}$) across major agroforestry systems (Source: synthesized from Feliciano et al., 2018).**

**Livelihood and Ecosystem Outcomes:** Local case studies revealed multiple co-benefits beyond carbon storage. **Figure 2** illustrates the proportional contribution of agroforestry to income security, soil and water health, biodiversity conservation, and climate mitigation.

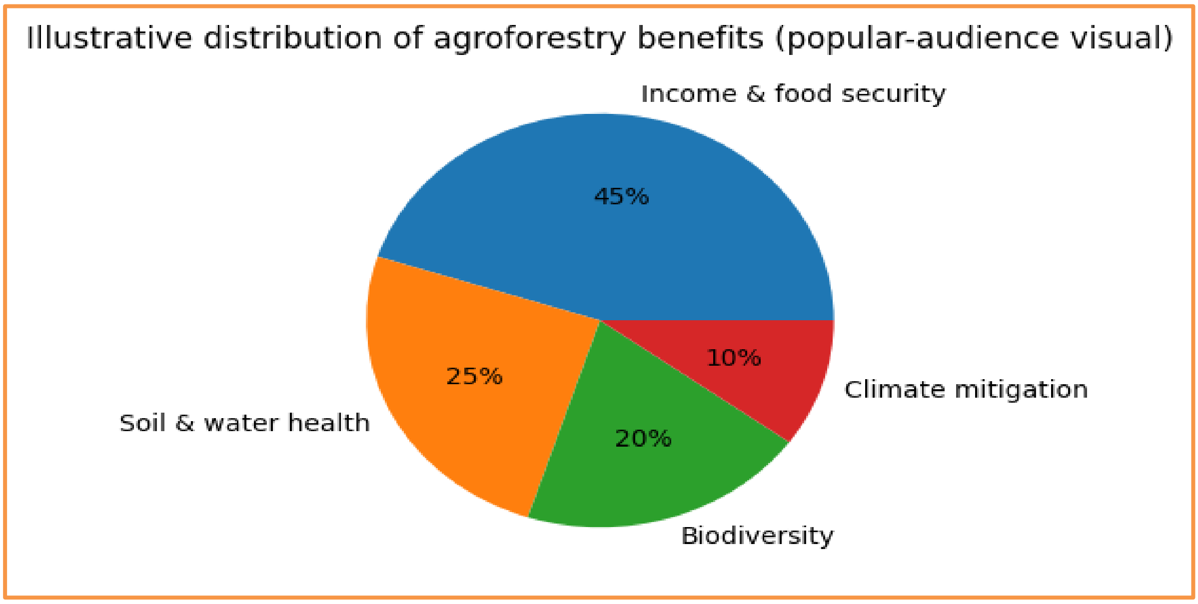


**Figure 2. Distribution of key benefits derived from agroforestry-based regenerative systems (illustrative synthesis from case studies and literature).**

The Wadi model demonstrated improved food security through fruit-based nutrition, enhanced women's participation via self-help groups, and long-term land productivity (BAIF, 2019). Kerala homegardens contributed to year-round income streams and high species diversity, reinforcing system resilience (Kumar & Nair, 2004).

## Discussion

The evidence confirms that agroforestry functions as a regenerative transition mechanism rather than a single intervention. The integration of trees enhances system complexity, which in turn stabilizes ecological functions and economic returns. Carbon sequestration benefits are particularly significant in long-term systems where tree biomass and soil carbon pools mature over time (Feliciano et al., 2018). Despite strong evidence, barriers such as delayed economic returns, limited extension support, and market access constraints remain challenges for wider adoption (ICRAF, 2022). Policy alignment, incentive mechanisms, and community-based institutional support are therefore essential for scaling regenerative agroforestry.

## Summary and Conclusion

This paper demonstrates that agroforestry-based regenerative transitions deliver measurable ecological and socio-economic benefits across scales. Evidence from global reviews and Indian case studies confirms improvements in carbon sequestration, soil health, biodiversity, and livelihood resilience. Agroforestry thus represents a viable and scalable pathway for sustainable agricultural transformation under climate change. Future efforts should focus on long-term monitoring, market integration, and policy support to mainstream regenerative agroforestry systems.

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