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Agroforestry's Soil Legacy: Enduring Benefits for Future Generations

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SUMMARY

Agroforestry is a sustainable farming practice that integrates trees into agricultural systems to enhance soil fertility, increase productivity, and ensure environmental sustainability. By intercropping trees into farming, agroforestry mitigates soil infertility, controls runoff and erosion, and maintains soil health which crucial for food security and livelihoods. It achieves this by increasing soil organic matter through litter fall and fine-root turnover, thus improving fertility and reducing nutrient losses. Moreover, agroforestry diversifies farm income by incorporating native tree species, promoting efficient land use, and providing various ecosystem services. Agroforestry also enhances biodiversity and carbon sequestration, surpassing conventional agricultural systems. The interaction of multiple plant species creates complex habitats that support diverse fauna, contributing to ecosystem resilience. With trees accounting for a significant portion of the global carbon pool, agroforestry plays a vital role in climate change mitigation and adaptation. Furthermore, the adoption of agroforestry practices benefits small-scale farmers by increasing carbon storage and improving livelihoods simultaneously. Agroforestry encompasses a wide range of systems and practices tailored to ecological, biophysical, and social factors, highlighting its versatility and adaptability to various contexts. Overall, agroforestry offers a holistic solution to address environmental degradation, food insecurity, and climate change, emphasizing the importance of sustainable land management practices for future generations.

INTRODUCTION

Agroforestry is viewed as a sustainable alternative to monoculture systems because of its ability to provide multiple ecosystem services. Now a days India faces crises of fuel, food, and fodder. Increasing population made this situation more critical, the last decade has seen an increase in scientific investigation and data that substantiate some of these claims. To reduce this effect researcher, suggest a unique land use system known as agroforestry. The integration of trees, agricultural crops, and/or animals into an agroforestry system has the potential to enhance soil fertility, reduce erosion, improve water quality, enhance biodiversity, increase aesthetics, and sequester carbon. Agroforestry practices also provide improved wildlife habitat by increasing structural and compositional plant diversity on the landscape. Agroforestry can be a good step to check deforestation and erosion in the hills. Agroforestry encompasses a wide variety of practices, including crop-fallow rotations, complex agroforests, simple agroforests, silvi-pastoral systems, and urban agroforestry. It plays a major role in enhancement of overall farm productivity, soil fertility through addition of litter and organic matter, climate change mitigation through carbon sequestration, phytoremediation, watershed protection and biodiversity conservation. Now a days farmers use planting trees along with crops improves soil fertility, control and prevents soil erosion, controls waterlogging, checks acidification and eutrophication of streams and rivers, increase local biodiversity, decrease pressure on natural forests for fuel and provide fodder for livestock.

Agroforestry systems are believed to increase, or at least maintain, the organic-matter levels in the soil. The soil microbial biomass has important functions in the soil, including nutrient cycling and the degradation of pollutants like pesticides, urban and industrial waste, etc. Organic level in the soil is positively connected with the number of microbial activities, which helps to decompose dead organic materials on-farm floor. Agroforestry promotes more efficient cycling of nutrients than traditional agriculture systems. It is also more sustainable and better for the environment. However, the amount of nutrient addition through litter decomposition varies from species to species. Leaf litter inputs to the ground floor serve as an important mechanism by which trees regulate ecosystem functions including nutrient and energy cycling, tree regeneration, and the maintenance of biological diversity and served valuable environment for adjoining agricultural crop. The withdrawal of nutrients from decomposed leaves and other plant parts proceeding to abscission allows a plant to use the same unit of nutrient to build several leaves or other plant parts successively through the soil nutrient cycling process. Agroforestry promotes the formers to divert their aim of cultivation from high production to sustainable cultivation. Soils

managed in sustainable and conventional farming systems with organic practices have shown high levels of organic matter (SOM) and total nitrogen. Improved fallow involves planting of fast-growing plant species that are usually nitrogen fixing tree, shrubs and herbaceous cover crops while other researcher focusses on multipurpose agroforestry systems which helps to increase soil fertility. Table 1 reveals some example of agroforestry systems which helps to enhance the soil fertility.

Table 1: Regional examples of soil fertility enhancement in multifunctional agroforestry systems in India

Region	Challenge	Changes observed due to agroforestry
Himalayas (Kurukshetra)	Improvement of sodic soils	Increase in microbial biomass, tree biomass and soil carbon, enhanced nitrogen availability
Himalayas	Restoration of abandoned agricultural sites	Biomass accumulation (3.9 t ha^{-1} in agroforests compared to 1.1 t ha^{-1} in degraded forests), improvement in soil physico-chemical characteristics, carbon sequestration
Western Himalayas	Reducing soil and water loss in agroecosystems in steep slopes	Contour tree-rows (hedgerows), reduced runn-off and soil loss by 40 and 48% respectively (in comparison to 347mm runoff, 39 Mg ha^{-1} soil loss per year under 1000mm rainfall conditions)
Sikkim Himalaya	Enhancing litter production and soil nutrient dynamics	Nitrogen fixing trees increase N and P cycling through increased production of litter and influence greater release of N and P, nitrogen-fixing species help in maintenance of soil organic matter, with higher N mineralization rates in agroforestry systems
Indo-Gangetic plains (UP)	Biomass production and nutrient dynamics in nutrient-deficient and toxic soils	Biomass production (49 t ha^{-1}/decade)
Himalayas (Meghalaya)	Enhancing tree survival and crop yield	Crop yield did not decrease in proximity to *Albizzia* trees
Western India (Karnal)	Improvement of soil fertility of moderately alkaline soils	Microbial biomass C which was low in rice-berseem crop (96.14 gg^{-1} soil) increased in soils under tree plantation (109.12 gg^{-1} soil) soil carbon increased by 11-52% due to integration of trees and crops
Western India (Rajasthan)	Compatibility of trees and crops	Density of 417 trees per ha was found ideal for cropping with pulses
Central India (Raipur)	Biomass production in N and P-stressed soils	*Azadirachta indica* trees per ha was found to produce biomass in depleted soils
Central India	Soil improvement	Decline n proportion of soil sand particles, increase in soil organic C, N, P and mineral N
Southern India (Kerala)	Growing commercial crops and trees	Ginger in interspaces of *Ailanthus triphysa* (2500 trees ha^{-1}) helps in getting better rhizome development of the former compared to solo cropping

Agroforestry practices have been shown to have positive effects on soil fertility, structure, moisture retention, and erosion control over extended periods. Here are some key long-term impacts:

Improved Soil Fertility: Agroforestry systems contribute to increased soil organic matter through the continuous input of litter fall, root turnover, and other organic residues from trees and crops. This organic matter enhances soil fertility by providing essential nutrients, improving soil structure, and promoting microbial activity. Over time, this enrichment can lead to sustained improvements in soil fertility and productivity.

Enhanced Soil Structure: The presence of tree roots in agroforestry systems helps to improve soil structure by creating macropores and enhancing soil aggregation. This improved soil structure enhances water infiltration, root penetration, and aeration, leading to better nutrient uptake by plants and overall soil health. Over the long term, these improvements can contribute to soil resilience and resistance to degradation.

Increased Soil Moisture Retention: Trees in agroforestry systems can help regulate soil moisture levels by intercepting rainfall, reducing evaporation, and improving water infiltration and retention in the soil profile. This increased soil moisture availability benefits crop growth and resilience to drought conditions, particularly in arid and semi-arid regions. Over time, improved soil moisture retention can contribute to more stable and productive agroecosystems.

Reduced Soil Erosion: Agroforestry practices, such as alley cropping, windbreaks, and contour planting, help to mitigate soil erosion by reducing the velocity of runoff, enhancing soil cover, and stabilizing slopes. The protective effect of tree canopies and root systems helps to minimize soil loss due to water and wind erosion, preserving soil fertility and structure over the long term.

Carbon Sequestration: Trees in agroforestry systems play a crucial role in sequestering atmospheric carbon dioxide through photosynthesis and storing carbon in biomass and soil organic matter. Over time, this carbon sequestration contributes to mitigating climate change and improving soil quality by increasing soil organic carbon content. Agroforestry systems can act as long-term carbon sinks, helping to offset greenhouse gas emissions from agricultural activities.

Enhanced Biodiversity: The diverse habitats provided by agroforestry systems support a wide range of plant and animal species, contributing to increased biodiversity over the long term. Trees, shrubs, and understory vegetation create niches for wildlife, pollinators, and beneficial organisms, promoting ecological balance and resilience. The preservation of biodiversity in agroforestry systems helps to maintain ecosystem services and enhance long-term agricultural sustainability.

CONCLUSION

Overall, the long-term impact of agroforestry systems on soil properties is characterized by improved fertility, structure, moisture retention, erosion control, carbon sequestration, and biodiversity conservation. These positive effects contribute to sustainable land management practices and support resilient and productive agroecosystems for future generations.

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