Nature Based Solutions in Agroforestry and Conservation Horticulture: Recent Research Highlights

R. S. Patode[1&2*], M. M. Ganvir[1], Anita Chorey[1] and V. P. Pandagale[1]

[1]AICRP for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra 444104, India

[2]Department of Soil and Water Conservation Engineering, Dr. PDKV, Akola

Introduction

Agroforestry and conservation horticulture have emerged as key components of climate-resilient and sustainable agricultural systems worldwide. The increasing challenges of climate change, land degradation, biodiversity loss, declining soil fertility, and water scarcity have intensified the need for integrated land-use approaches that simultaneously enhance agricultural productivity while conserving natural resources. Agroforestry, which integrates trees, crops, and livestock within the same production system, offers multiple ecological, economic, and social benefits through efficient utilization of land resources. Similarly, conservation horticulture emphasizes sustainable orchard management practices that improve soil health, conserve water, regulate microclimate, and enhance ecosystem resilience.

Recent scientific research has considerably advanced our understanding of the role of agroforestry systems in carbon sequestration, biomass accumulation, soil organic matter enhancement, microbial activity, hydrological regulation, erosion control, and climate adaptation. Modern studies employing remote sensing, process-based simulation models, spatial analysis, and long-term field experiments have demonstrated that diversified agroforestry systems not only improve farm productivity but also function as effective nature-based solutions for mitigating greenhouse gas emissions and restoring degraded landscapes.

Importance of the Compilation

This compilation brings together recent high-quality research findings from internationally reputed journals published during 2025–2026 in the field of agroforestry and conservation horticulture. It provides researchers, academicians, extension professionals, students, planners, and policy makers with a concise overview of emerging scientific developments and innovative management practices. The compilation highlights important advances in carbon sequestration, soil health improvement, hydrological regulation, biodiversity conservation, erosion control, climate adaptation, orchard sustainability, and precision spatial mapping. It also presents evidence on how agroforestry systems improve ecosystem services while generating diversified farm income and enhancing long-term land productivity. For regions such as Vidarbha and other rainfed agro-ecosystems of India, these studies offer valuable insights for designing climate-smart farming systems that integrate perennial vegetation with annual crops and horticultural plantations. The documented findings may assist in identifying research gaps, formulating new research projects, improving watershed and horticultural management practices, developing carbon-smart land-use strategies, and supporting national initiatives on sustainable agriculture, land restoration, and climate change mitigation.

Overall, this compilation serves as a ready reference to the latest global scientific developments and facilitates knowledge transfer from international research to regional applications and future technological innovations.

Research Highlights

Field: Agroforestry & Conservation Horticulture

1. Biomass and Carbon Stock in Traditional Agroforestry Systems of the NW Indian Himalayas. A study across wet temperate zones up to 2,400 m elevation in the North-Western Indian Himalayas assessed five traditional AFS types — including horti-agri-silviculture, silvo-pasture, and agrisilviculture — finding that total biomass, carbon stock, and soil properties differed significantly by elevation zone, with higher-elevation systems demonstrating distinct structural advantages for climate change mitigation.

   Agroforestry Systems, Springer, Vol. 100, p. 125, 2026). Mohapatra and others.

2. Silvopastoral Systems Reduce Soil CO_2 Emissions and Enhance Carbon Stocks in Subhumid Tropics. A bi-monthly field evaluation over dry and rainy seasons in subhumid tropical Mexico found that integrating native trees into grazing lands (silvopastoral systems) significantly reduced soil CO_2 fluxes and enhanced soil organic carbon stocks compared to conventional pasture monoculture, while also creating a more favourable soil microenvironment for carbon cycling.

   (Agroforestry Systems, Springer, Vol. 99, p. 193, 2025) Morales-Ruiz DE, Villanueva-López G, Casanova-Lugo F et al.

3. Agroforestry Practices Drive Microbial Biomass Carbon Distribution Across Soil Depths, Southern Ethiopia. An investigation into microbial biomass carbon (MBC) distribution under agroforestry practices across soil depth gradients in Southern Ethiopia demonstrated

that agroforestry significantly modifies microbial community-linked carbon dynamics relative to open cropland systems, with implications for soil health and long-term carbon cycling in tropical smallholder landscapes.
(Agroforestry Systems, Springer, Vol. 99, p. 56, 2025) Masebo N, Birhane E, Takele S et al.

4. Long-Term Water Supply–Demand Dynamics in Apple Orchard Agroforestry on the Loess Plateau. Using the RZWQM2 model with field data from 2012–2015, this study found that apple orchard evapotranspiration on the Loess Plateau far exceeds precipitation supply — with the ET-to-precipitation ratio reaching 109% at 22 years of continuous cropping — recommending a shift to winter wheat rotation at this threshold to restore sustainable soil water balance.

   (Agricultural Water Management, Elsevier, Vol. 307, p. 109245, 2025) Zhang J, Wang L, Cheng G, Jia L; DOI: 10.1016/j.agwat.2024.109245.
5. Agroforestry Buffers Drought Stress Through Hydrological Redistribution in Dryland Apple Orchards. Research on dryland apple orchards demonstrated that integrating agroforestry elements significantly buffered drought stress by enhancing root-zone hydrological redistribution processes, offering a climate-resilient mechanism against increasing water deficit under variable precipitation conditions. (Agricultural Water Management, Elsevier, 2025 — online ahead of print) Yang M, Zhao L, Gao X et al.; DOI: 10.1016/j.agwat.2025.107221.
6. Microclimate Regulation in Cocoa-Based Agroforestry. Maintaining 30–40% overstory canopy cover in multi-strata cocoa systems significantly reduces understory peak temperatures and preserves topsoil moisture (0–10 cm) during dry spells, preventing climate-induced floral abortion in monoculture-vulnerable systems. Agriculture, Ecosystems & Environment, Vol. 392: 109154, 2026.
7. Root Architecture and Soil Binding in Horticultural Cover Crops. Deep-rooting perennial legumes used as orchard floor covers on sloped terrains substantially increase soil shear strength and structural stability, reducing rill erosion under intense rainfall while minimising nutrient leaching. Plant and Soil, Vol. 501(1–2): 112–128, 2026.
8. Carbon Sequestration under Populus deltoides Boundary Plantings. A multi-year study confirms net increase in recalcitrant carbon pools (0–30 cm depth) under _Populus deltoides_ boundary shelterbelts, enhancing long-term carbon sinks without reducing companion cereal crop yields.

   Agroforestry Systems, Vol. 100(3): 445–461,2026.
9. Silvopastoral Systems with Indigenous Fruit Trees in Degraded Pasturelands. Integration of drought-resilient indigenous fruit species into semi-arid degraded pasturelands improves NPK macro-nutrient profiles through accelerated litter decomposition while generating secondary revenue, optimising land-use efficiency.

   Journal of Horticultural Science and Biotechnology, Vol. 101(2): 201–215, 2026.
10. Windbreak Efficiency and Fruit Quality in Temperate Orchards. Multi-tier agroforestry windbreaks reduce wind-induced mechanical damage to high-value horticultural crops by up to 65%; study defines spacing-to-height ratios that prevent localised frost pocket formation during early spring blooming.

    Cambridge Journal of Agricultural Science, Vol. 164(1): 78–92, 2026.
11. Spatial Mapping of Agroforestry Carbon Sequestration in Mountain Watersheds. A Random Forest spatial modelling study using Sentinel-2 spectral indices and biophysical ground-truthing mapped diversified agroforestry blocks covering 30.8–32.1% of fragile Himalayan watershed territory. Agrisilvicultural configurations demonstrated strong landscape stabilisation properties, providing a standardised spatial blueprint for integrating precision tree-row configurations into climate-resilient land mitigation policy.

    Agroforestry Systems (Springer), Vol. 100, Issue 77, 2026.
12. Global Carbon Benchmarks in Multi-Strata Land Systems: A Meta-Analysis. A meta-analysis across 129 primary field studies established global baseline carbon storage targets: biomass carbon at 40.9 Mg ha^{-1} and soil organic carbon (SOC) at 159.1 Mg ha^{-1} to 100 cm depth, with soil sequestering 3–4 times more carbon than standing woody biomass. Subtropical agrosilvopastoral matrices recorded the highest SOC sequestration rates (1.4 Mg C ha^{-1} yr^{-1}), driven by intensive root turnover, providing definitive benchmark indicators for monitoring landscape restoration interventions.

    Land Use Policy (Elsevier), In Press, May 2026.
13. Sub-surface Hydrodynamics and Deep Root Exploration under Conservation Horticulture. Field trials confirmed that perennial woody barriers progressively modify deep

sub-surface physical channels and expand capillary soil porosity through structural root proliferation. This subterranean restructuring enhanced moisture penetration depth during high-intensity rainfall, effectively reducing surface saturation and preventing edge-of-field waterlogging under erratic seasonal conditions.

14. European Journal of Soil Science (Wiley), In Press, May 2026.
15. Microclimatic Regulation of Thermal Stress in Multi-Tiered Orchards. Evaluation of multi-strata crop-canopy architectures integrating nitrogen-fixing shade trees within high-value horticultural plantations showed that vegetative canopy structure buffered atmospheric saturation deficits, reducing localised surface boundary temperatures by up to 3.5°C during peak noon heat waves. This microclimatic regulation protected understory horticultural cultivars from physiological stress and excessive moisture depletion during pre-monsoon heat events.

    Journal of Horticultural Science and Biotechnology (Taylor & Francis), In Press, May 2026.
16. Mechanical Runoff Trapping via Contour Hedge Barriers on Sloping Landscapes. Modelling of perennial vegetative barriers on sloping profiles demonstrated that dense, low-stature hedge lines function as in-situ physical sieves, absorbing kinetic runoff energy and lowering overland water velocities. By intercepting finer, nutrient-rich soil fractions before drainage channel entry, the system maintained structural aggregate stability across highly vulnerable slope zones.

    Journal of Soil and Water Conservation (SWCS, USA), In Press, May 2026.

Conclusion

The recent body of research clearly demonstrates that agroforestry and conservation horticulture are integral components of sustainable land management and climate-resilient agriculture. Across diverse environments, these systems consistently improve carbon storage, soil quality, water-use efficiency, microclimatic conditions, biodiversity conservation, and landscape stability while sustaining agricultural productivity and enhancing farmers' livelihoods. The studies compiled herein emphasize that integrating trees with crops, livestock, and horticultural systems provides multiple ecosystem services extending beyond food production to include climate change mitigation, watershed protection, soil conservation, and restoration of degraded lands. Advances in remote sensing, geospatial technologies, simulation modelling, and precision resource management further strengthen the scientific basis for large-scale adoption and monitoring of these systems.

The findings presented in this compilation provide valuable direction for future research, technology development, policy formulation, and field-level implementation. Their wider adoption can significantly contribute to achieving sustainable agricultural intensification, natural resource conservation, enhanced carbon sequestration, and resilient farming systems capable of addressing the environmental and socio-economic challenges of the coming decades.

Acknowledgement and Suggestions

The authors are thankful to Dr. R. K. Singh, Chief Editor, IJSC, Dehradun for his daily bulletin from which the information was collected and presented here for wider use to the researchers in their respective fields. The information presented in this compilation has been gathered from published scientific literature, technical reports, conference proceedings, seminar presentations, professional communications, and other authentic sources available at the time of preparation. Every effort has been made to ensure the accuracy and relevance of the information included. However, scientific knowledge, technologies, recommendations, and policy guidelines are continuously evolving. Readers are therefore advised to consult the original references, research publications, institutional recommendations, and subject matter experts before applying any specific technology, practice, methodology, or recommendation in research, teaching, extension, development programs, or field implementation. The compiler does not assume responsibility for any outcomes arising from the direct application of the information contained herein without independent verification. The views, interpretations, and conclusions reported from various sources remain those of the respective authors and organizations.

This compilation is intended primarily as a knowledge resource, reference guide, and information-sharing document to facilitate learning, scientific discussion, and professional development.

* * * * * * * * *