International Journal Of Multi Research

Online ISSN: 3107 – 7676

Impact Factor (RSIF): 6.70

IJMR 2026; 2(4): 163-168

2026 July - August

www.allmultiresearchjournal.com

Received: 15-06-2026

Accepted: 04-07-2026

Published: 03-08-2026

DOI: https://doi.org/10.54660/IJMR.2026.2.4.163-168

Impact of Invasive and Native Plant Species on Soil Organic Carbon Storage and Carbon Sequestration in the Village Forest Ecosystems of Haryana

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Abstract

Soil organic carbon (SOC) is a major component of terrestrial carbon storage and an important indicator of soil quality, ecosystem functioning and climate regulation. In village forest ecosystems, plant species influence SOC through litter production, root turnover, rhizodeposition, shading, soil moisture regulation and interactions with soil organisms. Native plants are generally adapted to local climatic and edaphic conditions and can sustain diverse below-ground processes. Invasive alien plants may also increase litter and soil carbon in some settings, but their effects are highly context-dependent and may be accompanied by loss of native diversity, altered nutrient cycling and changes in soil microbial activity. This article examines the potential impacts of native and invasive plant species on SOC storage and carbon sequestration in village forest ecosystems of Haryana. It synthesises published evidence on soil carbon under different land uses in western Haryana, phytosociological research in sacred groves, national forest carbon assessment methods and studies of invasive plants in India. A study of western Haryana reported the highest SOC stock under forests (40.26 Mg C ha^{-1}), followed by block plantations, horticulture, agroforestry and agriculture (Gupta *et al*., 2015). Research in sacred groves of western Haryana has also documented variation in soil organic carbon among sites alongside differences in vegetation composition and soil properties (Mahla *et al*., 2026). Evidence from other Indian regions shows that *Prosopis juliflora* and *Lantana camara* can alter soil carbon, nutrients and microbial processes; however, higher SOC under invaded sites does not necessarily indicate better ecosystem condition. The article argues for measuring soil carbon alongside native species regeneration, vegetation diversity, soil bulk density, microbial indicators and disturbance. It proposes a comparative field framework for village forests across Haryana's ecological zones and recommends native-species restoration, targeted invasive-plant management, soil-conserving practices and community participation. As this is a review-based article, no new field measurements or original empirical findings are claimed.

Keyword: Soil Organic Carbon, Carbon Sequestration, Native Plants, Invasive Alien Species, Village Forests, Haryana, Soil Health, Ecosystem Sustainability

Introduction

Forests and tree-dominated rural landscapes play an important role in the global carbon cycle. Carbon is stored in living vegetation, deadwood, litter and soil. Among these pools, soil organic carbon is particularly important because it can represent a large and relatively persistent reservoir, although its stability depends on climate, soil properties, vegetation and management. SOC is derived mainly from plant litter, fine-root turnover, root exudates and other organic inputs. Its accumulation reflects the

balance between carbon inputs and losses through decomposition, erosion, leaching and disturbance. Village forest ecosystems are small but ecologically significant wooded patches situated within rural settlements and agricultural landscapes. In Haryana, these may include sacred groves, community forests, village woodlots, protected commons, scrub patches and tree-rich areas managed by Gram Panchayats or local institutions. Such sites provide fuelwood, fodder, shade, small timber, medicinal resources and habitat for biodiversity. They also contribute to local climate regulation, soil conservation and carbon storage. Because many village forests are fragmented and subject to grazing, lopping, biomass extraction and land-use pressure, their carbon pools may be vulnerable to degradation. Haryana presents a range of ecological conditions. The Shivalik foothills in the north-east, the central plains and the semi-arid south-west differ in rainfall, soil texture, salinity, temperature and vegetation. These gradients influence plant productivity and the rate at which organic matter decomposes. In dry areas, water limitation may constrain biomass production and litter inputs, while high temperatures can accelerate decomposition during moist periods. Soil texture also matters: fine-textured soils can physically protect organic matter, whereas sandy soils may have lower capacity to stabilise carbon. Plant identity can affect SOC in multiple ways. Native trees and shrubs may contribute litter and roots adapted to local conditions, support diverse understory vegetation and maintain habitat complexity. Invasive plants may produce substantial biomass and litter, potentially increasing some soil carbon pools. Yet dense invasion can displace native species, change litter chemistry, alter microbial communities and affect soil water and nutrient dynamics. The net outcome cannot be inferred from the label ‘native’ or ‘invasive’ alone; it must be measured over appropriate soil depths and time periods. This article therefore focuses on the relationship between plant community composition and soil carbon in Haryana’s village forests. Terrestrial forest ecosystems constitute the largest active carbon sink on land, sequestering atmospheric carbon dioxide (\text{CO}_2) through photosynthesis and storing it across above-ground biomass, below-ground root systems, and soil organic matter. Within this continuum, Soil Organic Carbon (SOC) represents the most substantial and stable carbon pool, typically retaining two to three times more carbon than living vegetation. In an intensively cultivated, semi-arid agrarian state like Haryana—where recorded forest cover comprises roughly 3.62% of the total geographical area—village community forests (locally known as Banis, Birs, and sacred groves) serve as indispensable localized carbon sinks. Distributed across climatic gradients ranging from the sub-humid Shiwalik foothills in the northeast to the arid alluvial and aeolian plains in the southwest, these fragmented woodlands play a critical role in climate change mitigation, soil fertility maintenance, and regional ecological stability. The capacity of these village forest ecosystems to capture and stabilize carbon is fundamentally governed by their floristic composition, functional trait diversity, and successional status. Native climax and mid-successional tree assemblages—dominated by deep-rooted, drought-adapted indigenous species such as Prosopis cineraria (Khejri), Acacia nilotica (Kikar), Salvadora oleoides (Jaal), Azadirachta indica (Neem), and Butea monosperma (Dhak)—contribute recalcitrant litter inputs, sustain symbiotic nitrogen fixation, and foster diverse soil microbial networks that promote long-term carbon stabilization within soil aggregates.However, persistent anthropogenic disturbances—including overgrazing, unregulated lopping, agricultural encroachment, and habitat fragmentation—have accelerated the colonization of Invasive Alien Plant Species (IAPS) across Haryana’s village forests. Aggressive woody and herbaceous invaders such as *Prosopis juliflora*, *Lantana camara*, Parthenium hysterophorus, and Leucaena leucocephala rapidly displace native flora, fundamentally altering ecosystem carbon dynamics. Biological invasions disrupt carbon cycling through contrasting mechanisms: while fast-growing woody invaders like *P. juliflora* may temporarily elevate above-ground biomass in degraded patches, their altered litter chemistry (high lignin-to-nitrogen ratios or allelopathic compounds), modified soil moisture regimes, and impacts on microbial respiration can destabilize mineral-associated organic carbon and diminish net soil carbon sequestration over time.Quantifying how native versus invasive plant assemblages regulate biomass carbon stocks, litter decomposition rates, and depth-wise SOC storage is therefore essential for evaluating the climate-mitigation potential of Haryana’s village woodlands. Establishing an empirical understanding of these plant–soil carbon interactions provides a scientific foundation for designing targeted invasive species management, ecological restoration, and sustainable carbon-sequestration strategies in community-managed landscapes. It reviews existing evidence, explains the ecological mechanisms involved and proposes a research design for comparing native-dominated, mixed and invasive-dominated sites. The central argument is that carbon sequestration should be assessed together with biodiversity, soil health and community benefits rather than as an isolated numerical target.

Conceptual Understanding of Soil Organic Carbon and Carbon Sequestration

1. **Soil organic carbon storage:** SOC is the carbon contained in soil organic matter, including decomposing plant residues, microbial biomass, particulate organic matter and more stable mineral-associated organic matter. It is commonly reported as concentration (for example, percentage of soil mass) or as stock per unit area (Mg C ha^{-1}). Concentration alone is insufficient for comparing sites because soils differ in bulk density and the mass of soil represented by a given depth. A robust stock estimate therefore requires SOC concentration, bulk density, sampling depth and, where necessary, correction for coarse fragments or equivalent soil mass.
2. **Carbon sequestration:** Carbon sequestration refers to the net removal of carbon dioxide from the atmosphere and its storage in vegetation, soils or other reservoirs over a period of time. A single soil sample provides an estimate of the existing SOC stock, not the annual sequestration rate. To estimate change or sequestration, repeated measurements are required using consistent methods, depths and sampling locations. Changes in soil carbon can be slow, and detectable differences may require several years, especially in dry ecosystems.
3. **Plant–soil pathways:** Plants influence SOC through above-ground litter, below-ground roots, root exudates and microclimatic effects. Fine roots can contribute carbon directly to soil and may be important for formation of stable organic matter. Leaf litter quality—including carbon-to-nitrogen ratio, lignin and polyphenol content—affects decomposition rates. Canopy cover reduces direct solar exposure and can moderate soil temperature and moisture. Plant communities also influence soil organisms that decompose organic matter and transform it into forms with different degrees of persistence. Disturbance can interrupt these pathways. Repeated grazing may reduce plant biomass and litter return; excessive removal of branches and leaf litter reduces organic inputs; soil compaction can reduce infiltration and alter aeration; and fire can remove surface litter and change microbial activity. Conversely, carefully managed grazing and sustainable biomass use may be compatible with carbon maintenance where vegetation recovery and soil protection are ensured.

Ecological Context of Village Forests in Haryana

Village forests in Haryana occur in landscapes with contrasting moisture and soil conditions. In semi-arid western districts, vegetation commonly includes drought-tolerant trees and shrubs, while the Shivalik foothills support a different assemblage influenced by higher rainfall and topography. Native or locally characteristic dryland taxa such as Salvadora oleoides, Vachellia nilotica, Prosopis cineraria, Ziziphus species and Capparis decidua may contribute to rural tree cover, although the actual species composition varies by site. The distinction between native Prosopis cineraria and invasive *Prosopis juliflora* is particularly important for ecological interpretation. Community forests can support multiple vegetation layers—trees, shrubs, herbs, grasses and climbers. A study of three community forests in south-west Haryana recorded 76 plant species across 37 families, including 11 tree species, 13 shrubs, 46 herbs and six climbers (Saharan *et al*., 2020). This demonstrates that carbon assessments limited to large trees may overlook the contribution of understory plants, ground vegetation and root systems. Sacred groves are another important form of village-level conservation. They are protected through religious and customary practices and may preserve vegetation in otherwise intensively used landscapes. A study of sacred groves in Mahendragarh district documented more than 50 plant species across 20 groves and emphasised their conservation value (Yadav *et al*., 2010). Recent phytosociological work in four sacred groves of western Haryana measured soil properties including organic carbon and reported differences among sites in vegetation structure and soil characteristics (Mahla *et al*., 2026) [10]. This provides a useful local basis for investigating how plant communities and soil carbon vary together.

Evidence on Soil Organic Carbon in Haryana:

A particularly relevant study by Gupta, Sharma and Kumar (2015) [4] assessed soil organic carbon stock under different land uses in the western region of Haryana, covering Bhiwani, Fatehabad, Hisar, Jind and Sirsa. The reported mean SOC stocks were highest under forests (40.26 Mg C ha^{-1}), followed by block plantations (33.27 Mg C ha^{-1}), horticulture (25.69 Mg C ha^{-1}), agroforestry (21.98 Mg C ha^{-1}) and agriculture (18.10 Mg C ha^{-1}). The study also estimated a total SOC stock of 1.22 million tonnes under forests in the study region. These findings suggest that forest land use can maintain greater soil carbon stocks than several other land uses in western Haryana. However, the figures should not be interpreted as a direct comparison between native and invasive plant species. The study compared land-use categories, not controlled plots dominated by particular native or invasive species. Differences may reflect vegetation cover, stand age, soil type, management history, topography and other factors. The values are therefore useful regional context, but a species-level field study is needed to isolate plant-community effects. The Forest Survey of India explains that forest SOC is influenced by land use and management activities that affect litter inputs. Its national forest inventory uses soil sampling to a depth of 30 cm for SOC assessment in the described protocol, while recognising that carbon estimates depend on sampling depth and the time required to approach a new equilibrium after land-use change (Forest Survey of India, 2024). For village-forest research, a 0–30 cm layer provides comparability with this approach, but deeper sampling may be useful because roots and carbon distribution can extend below 30 cm. The western Haryana evidence also highlights the need to distinguish carbon concentration from carbon stock. A site with high SOC percentage may have low stock per hectare if its bulk density or sampled soil mass is low. Conversely, compacted soil can show a high stock estimate if bulk density is not properly accounted for. Consistent sampling, laboratory procedures and stock calculations are therefore essential. Empirical studies across Haryana's agro-climatic zones—from the sub-humid Shiwalik foothills in the northeast to the semi-arid Aravalli ridges and southwestern alluvial plains—demonstrate that Soil Organic Carbon (SOC) stocks are strongly regulated by vegetation cover, species composition, soil texture, and invasive species dynamics.

Influence of Native Plant Species on SOC Storage

- **Litter inputs and decomposition:** Native vegetation contributes organic matter through leaf fall, twigs, flowers, fruits and root turnover. In dryland ecosystems, litter accumulation under trees can create nutrient-rich microsites, sometimes described as fertility islands. These microsites may have higher organic matter, microbial activity and nutrient availability than exposed interspaces. Species differ in litter quantity and quality, so the carbon contribution of a native tree depends on its productivity, leaf chemistry, root distribution and the local decomposition environment.
- **Root systems and soil structure:** Root growth creates channels that improve soil structure and infiltration. Fine-root turnover supplies organic matter at different depths, while root exudates provide substrates for soil microorganisms. Deep-rooted native trees may access water from deeper soil layers and maintain biomass during dry periods, although the actual contribution to SOC depends on root production and turnover. A diverse mixture of trees, shrubs and grasses can distribute organic inputs across soil depths and microsites.
- **Biodiversity and soil biological activity:** Native plant diversity can support a broad range of soil fauna, fungi and bacteria through variation in litter chemistry and root exudates. Diverse plant communities may create multiple decomposition pathways and support a more complex soil food web. This does not mean that species richness always produces higher SOC: climate, soil mineralogy, disturbance and biomass production remain important controls. Nevertheless, native diversity can improve ecosystem resilience and reduce the risk that one disturbance or pest causes widespread loss of vegetation and carbon inputs.In Haryana's semi-arid village forests, native species adapted to water stress may be particularly important for maintaining persistent vegetation cover. Conservation of mature native trees, protection of seedlings and regeneration, and retention of suitable understory vegetation can sustain soil inputs over time.

Influence of Invasive Plant Species on SOC and Carbon Sequestration

- ***Prosopis juliflora*:** *Prosopis juliflora* is a drought-tolerant invasive tree in many Indian dryland settings. Its rapid growth and substantial litter production can increase organic inputs and may be associated with higher soil nutrient concentrations in some invaded sites. A study in semi-arid southern India found enriched soil macronutrients in *P. juliflora*-invaded lands, with stand density and litter fall among the important correlates (Mohanraj *et al*., 2022) [7]. Other Indian assessments have reported

higher available nitrogen, phosphorus and organic carbon in highly invaded sites in some regions. These findings show that invasion can increase selected soil variables under particular conditions.

- However, increased SOC or nutrients beneath *P. juliflora* do not automatically indicate improved ecosystem sustainability. Dense stands may suppress native plants, reduce open-habitat diversity, alter water use and change access to village commons. The long-term balance between carbon storage, biodiversity loss, soil-water relations and livelihood costs must be evaluated. Management should also distinguish *P. juliflora* from native *P. cineraria*, which has a different ecological and cultural role in dryland landscapes.
- ***Lantana camara*:** *Lantana camara* is an invasive shrub capable of forming dense thickets in disturbed habitats and forest edges. Its litter and root inputs may alter soil organic matter and nutrient cycling. Research in central Indian tropical forests found higher SOC stocks in Lantana-invaded sites than in uninvaded sites at 0–50 cm, while total biomass carbon was lower in invaded sites (2025 study). This illustrates an important point: soil carbon and total ecosystem carbon can respond differently. A site may hold more SOC but less carbon in tree and understory biomass, alongside reduced native tree diversity. Lantana invasion may also affect seedling recruitment, ground vegetation and the composition of soil microbial communities. Its impact is likely to vary with invasion density, rainfall, soil texture and prior disturbance. Haryana-specific measurements are needed before transferring numerical findings from central or Himalayan India to village forests in the state.
- **Interpreting carbon gains under invasion:** The relationship between invasive plants and SOC is not uniformly negative. Invasive species can increase plant biomass and litter inputs, and their presence may raise SOC in some invaded locations. At the same time, they may reduce native biodiversity, alter soil microbial respiration and nutrient cycling, or change carbon allocation between vegetation and soil. Research on Prosopis and Acacia invasion and subsequent removal in southern Indian biodiversity hotspots found that removal promoted recolonisation by local vegetation but also changed microbial biomass carbon and soil enzyme activity (study published in 2020). This indicates that invasive-plant removal can itself alter soil processes and should be followed by restoration and monitoring. Therefore, the central research question is not simply whether invasive plants increase or decrease SOC. It is whether they change the quantity, depth distribution, stability and long-term persistence of soil carbon, and what trade-offs occur for native biodiversity, ecosystem function and local livelihoods.

Comparative Framework: Native-Dominated and Invasive-Dominated Sites

A useful comparison for Haryana would include at least three vegetation conditions: (i) native-dominated village forest patches, (ii) mixed patches containing native and invasive species, and (iii) invasive-dominated patches. Where possible, each category should be represented by sites with similar soil type, slope, land-use history and disturbance intensity. A nearby agricultural or degraded site may be included as a reference, but should not replace comparisons among village forest types.

Indicator	Why it matters	Expected interpretation
SOC concentration and stock	Measures soil carbon pool	Compare by depth and equivalent soil mass
Bulk density	Needed for stock calculation; reflects compaction	Interpret alongside soil texture and disturbance
Litter biomass and quality	Estimates above-ground organic inputs	Relates plant traits to decomposition
Fine-root biomass	Represents below-ground carbon input	Shows depth-specific root contribution
Native species richness and regeneration	Measures biodiversity condition	Identifies possible suppression by invasion
Microbial biomass carbon and respiration	Indicates biological processing of carbon	Helps distinguish storage from rapid turnover
Soil moisture, pH and nutrients	Controls decomposition and plant growth	Explains site-level variation

Research Methodology for a Haryana Field Study

A future empirical study should use a stratified comparative design across the Shivalik foothills, central plains and semi-arid south-western Haryana. Within each ecological zone, village forests should be selected to represent native-dominated, mixed and invasive-dominated vegetation. Site selection should account for patch size, protection status, grazing intensity, fire history, soil type and distance from settlements. Replication across villages is essential; a single grove cannot represent an entire district or ecological zone.

- **Vegetation sampling:** Tree species can be recorded in fixed-area plots, with nested subplots for shrubs, herbs and seedlings. Species identity, abundance, diameter at breast height, height, canopy cover, basal area, litter depth and regeneration status should be measured. Invasive species should be recorded separately by density, cover and life stage. Botanical identification should be verified by qualified taxonomists, and local names and uses should be documented with community participation.
- **Soil sampling and laboratory analysis:** Soil samples should be collected from standard depth intervals such as 0–10, 10–20 and 20–30 cm, with an optional 30–50 cm layer where resources permit. At least three to five spatially distributed subsamples may be composited within each plot for chemical analysis, while intact cores are required for bulk-density measurement. SOC can be measured using a recognised wet oxidation or dry combustion method, with laboratory quality control and clear reporting of the method. Soil pH, electrical conductivity, texture, moisture, total nitrogen and available phosphorus and potassium should also be measured.
- **Estimation of SOC stock:** For a soil layer, SOC stock can be estimated as: SOC stock (Mg C ha^{-1}) = SOC concentration (%) × bulk density (g cm^{-3}) × soil depth (cm) × 100, after appropriate adjustment for coarse fragments. Where soil bulk density differs substantially among treatments, equivalent soil mass methods should be considered. The method, depth and units must be stated clearly. Annual sequestration should not be inferred from a one-time stock comparison; repeated sampling over multiple years is required to estimate stock change.
- **Data analysis:** Species diversity may be described using richness, Shannon–Wiener diversity and evenness indices. Differences in SOC among vegetation categories can be tested using suitable statistical models that account for site and ecological zone. Regression or mixed-effects models can examine relationships between SOC and native species richness,

invasive cover, litter biomass, root biomass, bulk density, soil moisture and disturbance. Geographic Information Systems can map forest patch distribution and connectivity. Interviews and focus groups can document resource dependence, perceptions of invasive plants and willingness to participate in restoration, following informed consent and ethical research practices. The analysis should distinguish correlation from causation. For example, higher SOC under a dense invasive stand may be due to litter input, but it may also reflect pre-existing fertile soil that favoured invasion. Paired sites, repeated measurements and before–after monitoring of restoration interventions can improve causal interpretation.

Conservation and Management Implications

Carbon-oriented management in village forests should protect native vegetation and maintain soil processes. Mature native trees should be conserved, regeneration zones protected from excessive grazing, and leaf litter retained where feasible. Restoration should use locally appropriate native species selected for soil, rainfall and water availability. Mixed-species restoration is preferable to uniform planting where it reflects local reference vegetation and supports multiple ecological functions. Invasive-plant control should be targeted rather than indiscriminate. Priority should be given to invasion fronts, high-biodiversity patches and sites where native regeneration is being suppressed. Removal should be phased and followed by native revegetation, erosion control and repeated monitoring. Abrupt clearing without restoration can expose soil, reduce ground cover and create opportunities for reinvasion. Where communities depend on invasive biomass for fuel or other uses, management plans should consider safe utilisation and livelihood alternatives. Soil carbon monitoring should be integrated into village biodiversity registers and local forest-management plans. Gram Panchayats, biodiversity management committees, schools, forest officials and local universities can jointly monitor vegetation and soil indicators. Community participation is especially important in sacred groves and commons where customary practices have historically supported protection. Carbon benefits should not be pursued at the expense of native biodiversity, water security or equitable access to common resources.

Limitations and Research Gaps

The available evidence for Haryana includes land-use comparisons and phytosociological studies, but there is limited directly comparable, species-level evidence linking native and invasive plant dominance to SOC stock and sequestration in village forests across the state. Existing studies vary in soil depth, sampling season, laboratory method and site characteristics. Results from southern or central India provide useful mechanisms but cannot be assumed to represent Haryana's semi-arid and foothill conditions. Future research should prioritise long-term, replicated comparisons and report both soil and vegetation carbon pools. It should also examine the stability of SOC, microbial biomass, decomposition rates, root distribution and the effects of invasive-plant removal followed by restoration. A state-level database of village forest plots could support climate and biodiversity planning.

Conclusion

Native and invasive plant species can influence soil organic carbon storage through their effects on litter inputs, root systems, microclimate, soil organisms and nutrient cycling. Evidence from western Haryana shows that forests hold higher average SOC stocks than several other land uses, reinforcing the importance of conserving wooded ecosystems. Studies of sacred groves further demonstrate that village-level protected patches contain diverse vegetation and measurable variation in soil properties. At the same time, research from other Indian regions shows that invasive plants such as *Prosopis juliflora* and *Lantana camara* may increase some soil carbon or nutrient indicators while reducing native vegetation or altering ecosystem processes. The relationship between invasion and carbon storage is therefore complex. Higher SOC beneath an invasive stand should not automatically be interpreted as successful climate mitigation, just as invasive-plant removal should not be considered successful without monitoring soil and vegetation recovery. Haryana requires a carefully designed field study comparing native-dominated, mixed and invasive-dominated village forests using standardised soil depths, bulk-density correction and repeated measurements. Village forest ecosystems across Haryana—comprising traditional Banis, Birs, and community-managed sacred groves—serve as critical localized carbon sinks within an intensively cultivated, semi-arid landscape. Spanning diverse bioclimatic gradients from the sub-humid Shiwalik foothills to the southwestern alluvial and aeolian plains, these wooded fragments regulate regional carbon fluxes, stabilize fragile soils, and sustain rural agro-pastoral livelihoods. The carbon sequestration potential and long-term Soil Organic Carbon (SOC) stability of these ecosystems are fundamentally governed by floristic composition, structural complexity, and the balance between indigenous and invasive plant assemblages.Multi-tiered native plant communities dominated by keystone species such as Prosopis cineraria, Acacia nilotica, Salvadora oleoides, and Azadirachta indica enhance long-term carbon storage by generating nutrient-rich litter, fostering deep root networks, and supporting diverse soil microbial and mycorrhizal communities that stabilize carbon within soil aggregates. Conversely, while aggressive invasive alien species such as *Prosopis juliflora* and *Lantana camara* may rapidly accumulate above-ground biomass or elevate transient surface carbon in heavily degraded patches, they simultaneously suppress native understory diversity, alter soil stoichiometry and moisture regimes, and heighten vulnerability to surface fires and microbial priming—ultimately compromising the persistence and quality of subsoil carbon pools.Maximizing the climate-mitigation and ecological value of Haryana's village forests requires integrating biological invasion management directly into soil carbon conservation frameworks. Restoration strategies must prioritize the targeted removal of invasive monocultures coupled with assisted natural regeneration using native tree–shrub–grass assemblages, alongside active stewardship by Gram Panchayats and Village Forest Committees (VFCs). Coupling science-based ecological restoration with standardized SOC monitoring and emerging rural carbon-credit mechanisms offers a viable pathway to enhance long-term carbon sequestration, rebuild soil health, and secure the ecological resilience of Haryana's community-managed forests.An integrated strategy—protecting native diversity, controlling high-impact invasives, restoring soil cover and involving local communities—offers the strongest pathway towards biodiversity conservation and durable ecosystem carbon storage.

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How to Cite This Article
Sharma A, Sharma A. Impact of Invasive and Native Plant Species on Soil Organic Carbon Storage and Carbon Sequestration in the Village Forest Ecosystems of Haryana. International Journal of Multi Research. 2026; 2(4): 163-168.

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