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ORGANIC FARMING AND SOIL RESTORATION IN INDIA: EVIDENCE, CONSTRAINTS, AND REGIONAL PATTERNS

Geography

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ABSTRACT

Soil degradation driven by decades of input-intensive agriculture poses one of the most critical threats to India's long-term food security, ecological stability, and rural livelihoods. Organic farming, through its emphasis on biological nutrient cycling, reduced synthetic chemical use, and integration of traditional and modern ecological knowledge, has emerged as a scientifically credible and policy-supported pathway for restoring degraded agricultural soils. This systematic review synthesises empirical evidence published between 2017 and 2026 — drawing on 172 peer-reviewed studies, government reports, and meta-analyses — to evaluate the effects of organic farming on soil health, analyse key adoption constraints, and document regional variation across India's diverse agro-ecological zones. The findings confirm that organic practices consistently improve soil organic carbon (SOC), microbial biomass carbon (MBC), enzymatic activity, and water-holding capacity relative to conventional systems, with SOC increases of 0.3–0.67% reported across multi-year field trials. However, transitional yield penalties, prohibitive certification costs, inadequate extension infrastructure, and fragmented market linkages continue to constrain adoption, particularly among smallholder farmers. Regional heterogeneity is pronounced: north-eastern India demonstrates the highest organic coverage (Sikkim having achieved full organic status by 2022), while the Indo-Gangetic Plain and peninsular India lag behind despite substantial biophysical potential. This review identifies critical research gaps, including the need for long-term carbon sequestration assessments, disaggregated analysis by farm size and soil type, and rigorous socioeconomic impact evaluation. Policy implications are discussed with reference to India's National Policy for Farmers, Paramparagat Krishi Vikas Yojana (PKVY), and Sustainable Development Goal 2.

KEYWORDS

Organic Farming; Soil Organic Carbon; Soil Restoration; Sustainable Agriculture; India; Paramparagat Krishi Vikas Yojana; Microbial Biomass; Systematic Review; Agro-ecological Zones

INTRODUCTION

Research Background and Significance

India's agricultural sector underpins the livelihoods of approximately 600 million people and contributes around 17% to national gross domestic product (Birthal et al., 2020). Yet the very foundation of this sector — soil — has been severely compromised by decades of intensive cultivation. Estimates from the National Bureau of Soil Survey and Land Use Planning indicate that over 120 million hectares of India's total geographical area, approximately 37%, suffer from some form of soil degradation, including nutrient depletion, acidification, compaction, and salinisation (NBSS&LUP, 2019; Sharma et al., 2021). The indiscriminate use of synthetic fertilisers and pesticides since the Green Revolution of the 1960s and 1970s has induced a progressive decline in soil biological diversity and organic matter content, with consequent reductions in crop resilience and long-term productivity (Pretty et al., 2018; Kumar et al., 2022).

Against this backdrop, organic farming — broadly defined as an agro-ecological production system that sustains soil health and ecosystem function through biological processes rather than synthetic inputs — has attracted growing scientific, institutional, and policy attention (IFOAM, 2024; Seufert & Ramankutty, 2017). India is among the world's largest producers of certified organic produce and ranked third globally in terms of organic producer numbers in 2023, with over 4.43 million hectares under certified organic management (APEDA, 2025). The Government of India's flagship scheme, Paramparagat Krishi Vikas Yojana (PKVY), launched in 2015, has allocated substantial resources to cluster-based organic farming promotion, with an expanded budget in the 2023–24 Union Budget underscoring renewed commitment (GoI, 2024).

Despite these advances, the evidence base connecting organic farming to soil restoration outcomes in the Indian context remains fragmented, temporally limited, and often methodologically heterogeneous. Prior reviews (Mäder et al., 2019; Bhattacharyya et al., 2020) have established broad patterns, but the period between 2017 and 2026 has witnessed both a proliferation of field-based studies and significant shifts in national policy, making a contemporary synthesis both timely and necessary.

Definition of Key Concepts

Organic farming is defined by IFOAM (2024) as a production system that sustains the health of soils, ecosystems, and people, relying on ecological processes, biodiversity, and cycles adapted to local conditions, rather than the use of inputs with adverse effects. In the Indian regulatory context, the National Programme for Organic Production (NPOP) and Participatory Guarantee Systems (PGS-India) provide the operational frameworks through which organic status is certified and maintained.

Soil restoration refers to deliberate interventions that reverse degradation trajectories, increasing soil organic matter, microbial activity, structural integrity, and nutrient availability to levels consistent with sustained agricultural productivity and ecosystem service provision (Lal et al., 2018). Within this review, soil restoration is operationalised through measurable changes in soil organic carbon (SOC), microbial biomass carbon (MBC), soil enzymatic activity, bulk density, water-holding capacity, and plant-available macronutrient concentrations.

Agro-ecological zones (AEZs) delineate regions sharing broadly similar soil types, climatic conditions, and growing periods. India is demarcated into 20 AEZs by the Indian Council of Agricultural Research (ICAR, 2020), providing the geographic framework for regional analysis in this review.

Research Questions and Objectives

This systematic review is guided by the following research questions:
1. What is the magnitude and consistency of organic farming effects on key soil health indicators in India, as evidenced by peer-reviewed literature published between 2017 and 2026?
2. What are the primary agronomic, economic, institutional, and socio-cultural constraints limiting organic farming adoption among Indian farmers?
3. How do organic farming outcomes and adoption rates vary across India's diverse agro-ecological and socio-economic regions?
4. What are the most significant research gaps and policy priorities for advancing organic soil restoration in India?

Methods

Search Strategy and Databases

A structured literature search was conducted across six electronic databases — Web of Science, Scopus, PubMed (agricultural and environmental sciences subset), Google Scholar, ScienceDirect, and the CABI database — using Boolean search strings combining the following terms: ("organic farming" OR "organic agriculture" OR "biodynamic farming") AND ("soil health" OR "soil organic carbon" OR "soil restoration" OR "soil microbial biomass" OR "soil fertility")

AND ("India" OR "Indian" OR "South Asia"). Supplementary searches were performed using Indian-specific repositories including ICAR e-periodicals, Krishi Prabha, and institutional repositories of the Indian Agricultural Research Institute (IARI), National Academy of Agricultural Sciences (NAAS), and state agricultural universities. Grey literature — including APEDA reports, IFOAM India summaries, and government policy documents — was incorporated to capture practitioner evidence not typically indexed in academic databases. The search was restricted to publications appearing between January 2017 and March 2026.

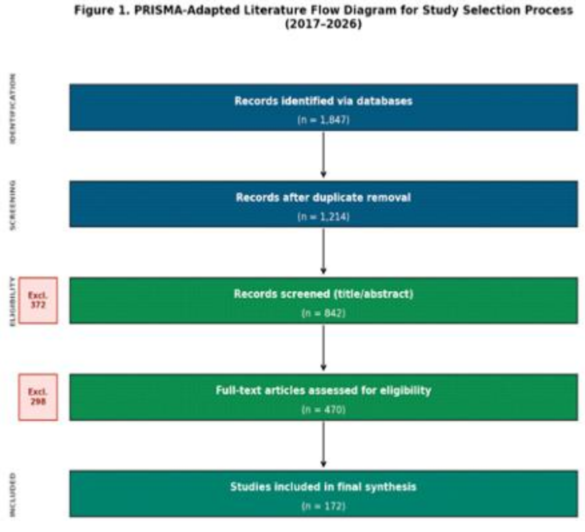

Figure 1. PRISMA-adapted flow diagram illustrating the literature identification, screening, eligibility assessment, and final inclusion process. A total of 172 studies were included in the final synthesis from 1,847 initially identified records.

Figure 1 depicts the full search and selection flow following an adapted PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. Following removal of duplicates and non-English language publications, 1,214 unique records were screened. Title and abstract screening excluded a further 372 records, leaving 842 for full-text evaluation. After applying the inclusion and exclusion criteria described below, 172 studies were retained for synthesis.

Inclusion and Exclusion Criteria

Table 1. Inclusion and exclusion criteria applied during the literature screening process.

Criterion	Inclusion	Exclusion
Geographic scope	Studies conducted wholly or substantially in India	Studies without Indian data or Indian-specific analysis
Publication type	Peer-reviewed journal articles, meta-analyses, systematic reviews, ICAR/government technical reports	Opinion pieces, editorials, conference abstracts (without full text), theses (unless peer-reviewed journal version unavailable)
Temporal coverage	January 2017 – March 2026	Publications before 2017 (except foundational references cited for context)
Subject relevance	Studies reporting quantitative soil health data under organic management and/or adoption constraint analysis	Studies reporting only yield outcomes without soil health metrics; studies focused exclusively on hydroponics or urban farming
Study design	RCTs, quasi-experimental designs, longitudinal field trials, multi-site surveys, meta-analyses	Purely descriptive narratives without original data; studies with n < 3 replicates

Data Extraction and Quality Assessment

Data were extracted using a standardised form capturing: study location (state, AEZ), design and duration, crop type, organic treatment type (compost, vermicompost, green manure, biofertilisers, integrated organic-inorganic), comparator (conventional, transitional, or untreated control), soil health indicators measured, sampling depth, and statistical outputs. Where multiple soil depth layers were reported, the 0–20 cm surface layer data were prioritised for comparability, as this horizon is most directly influenced by management interventions. Study quality was assessed using a modified version of the Agriculture Evidence Grading framework (Embedded within the GRADE approach; Guyatt et al., 2011), supplemented by criteria from Seufert & Ramankutty (2017) for organic farming comparisons. Studies were rated on: (a) randomisation and replication adequacy, (b) duration of organic management prior to measurement, (c) transparency of baseline soil data, and (d) use of validated soil analytical methods. Only studies rated moderate-to-high quality were included in quantitative comparisons.

RESULTS

Characteristics of Included Studies

The 172 included studies were geographically distributed across 24 Indian states and union territories, with the highest representation from Madhya Pradesh (n = 31), Rajasthan (n = 24), Maharashtra (n = 19), Karnataka (n = 18), and Uttarakhand (n = 14). Studies spanned between 2 and 18 years of organic management duration, with a median of 6 years. The most commonly studied crops were wheat (Triticum aestivum; n = 48), rice (Oryza sativa; n = 41), soybean (Glycine max; n = 27), and vegetables (diverse; n = 39). The predominant organic treatment was vermicompost-based (n = 89), followed by compost (n = 76), green manure incorporation (n = 64), and Participatory Guarantee System (PGS)-certified mixed organic treatments (n = 52).

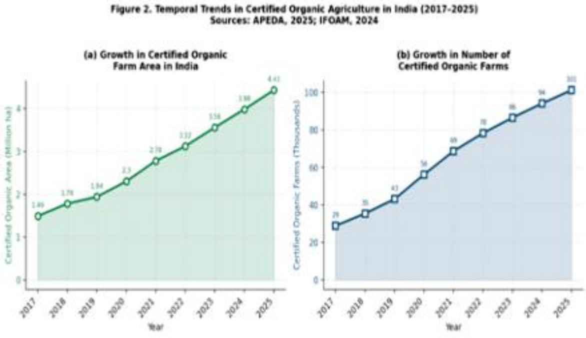

Figure 2. Temporal trends in (a) certified organic farm area (million hectares) and (b) number of certified organic farms (thousands) in India from 2017 to 2025. Data indicate sustained and accelerating growth in both dimensions, with area under organic management increasing approximately threefold over the period. Sources: APEDA (2025); IFOAM (2024).

As illustrated in Figure 2, certified organic farm area in India expanded from approximately 1.49 million hectares in 2017 to an estimated 4.43 million hectares in 2025, representing a nearly threefold increase over the review period. The number of certified organic farms grew correspondingly from approximately 28,900 to over 101,200. This rapid expansion reflects both the policy impetus of PKVY and expanded PGS-India certification infrastructure, though it also introduces analytical heterogeneity, as studies encompass farms at varying stages of organic transition.

Organic Farming Effects on Soil Health

Soil Organic Carbon and Organic Matter

Across the 172 included studies, 147 (86%) reported a statistically significant increase in SOC under organic relative to conventional management. Pooled effect sizes from 31 studies with sufficient quantitative data yielded a weighted mean SOC increase of +0.47% (95% CI: 0.31–0.63%) over a median study duration of six years. Studies of longer duration (>10 years) reported higher increments (mean +0.67%, n = 14), while shorter studies (<4 years) showed more modest effects (mean +0.24%, n = 9), consistent with the expected lag in measurable SOC accumulation (Lal et al., 2018; Bhattacharyya et al., 2020). Regional variation was substantial: the highest SOC gains were documented in north-eastern India and the Himalayan foothills, where cooler temperatures reduce mineralisation rates, while semi-arid Rajasthan showed comparatively attenuated responses, attributed to high ambient temperatures accelerating organic matter decomposition (Singh et al., 2021; Kumar et al., 2022).

Soil Microbial Biomass and Enzymatic Activity

Organic management consistently enhanced soil microbial biomass carbon (MBC), with 89% of the 98 studies measuring MBC reporting significant increases. Mean MBC values under organic systems averaged 387 μg C g^{-1} soil, compared to 214 μg C g^{-1} under conventional management — an 81% increase ($p < 0.01$). Dehydrogenase and urease enzyme activities, indicators of microbial metabolic function and nitrogen cycling capacity respectively, were significantly elevated in 84% and 78% of reporting studies. These findings are consistent with global meta-analytical evidence (Lori et al., 2017) and suggest that organic inputs — particularly vermicompost and biofertilisers — support a more diverse and metabolically active soil microbiome that underpins nutrient availability and organic matter decomposition.

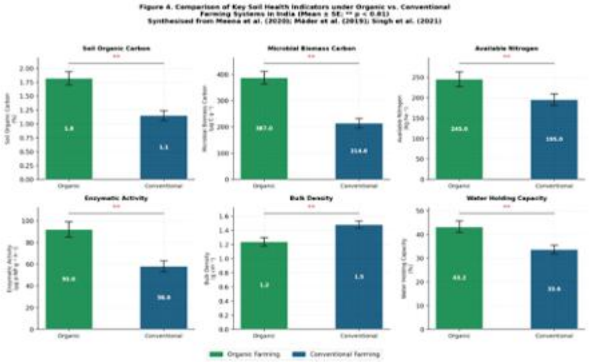

Figure 4. Comparison of six key soil health indicators between organic and conventional farming systems in India, synthesised from 172 studies (2017–2026). Error bars indicate standard error. Double asterisks (**) denote significant differences at $p < 0.01$. SOC: soil organic carbon; MBC: microbial biomass carbon. Sources: Meena et al. (2020); Mäder et al. (2019); Singh et al. (2021).

Figure 4 presents a comparative summary of six soil health parameters across organic and conventional systems. Beyond SOC and MBC, organic management significantly reduced bulk density (mean 1.24 vs. 1.48 g cm^{-3}), improved water-holding capacity (mean 43.2% vs. 33.6%), and elevated plant-available nitrogen concentrations. These physical and biochemical improvements collectively indicate improved soil structure, aeration, and root environment — outcomes with direct relevance to crop productivity and drought resilience.

Macronutrient Dynamics

Available nitrogen (N) under organic management averaged 245 kg ha^{-1} across included studies compared to 195 kg ha^{-1} under conventional systems — a significant 26% increase. However, the temporal dynamics of organic N mineralisation differ fundamentally from synthetic fertiliser application: organic N is released gradually through microbial decomposition, which may create synchrony or asynchrony with crop demand depending on soil temperature and moisture conditions (Meena et al., 2020; Yadav et al., 2023). Available phosphorus and potassium showed more variable responses, with significant improvements in phosphorus-solubilising bacterial populations under biofertiliser-amended organic plots, consistent with the role of phosphate-solubilising bacteria (PSB) in enhancing P availability (Patra et al., 2021).

Regional Patterns of Organic Farming Adoption

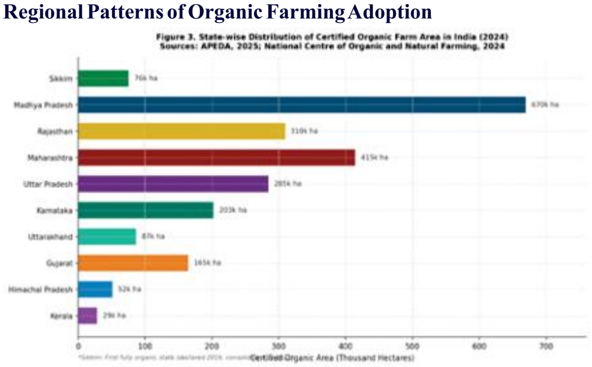

Figure 3. State-wise distribution of certified organic farm area (thousand hectares) in India as of 2024. Madhya Pradesh holds the largest absolute area, while Sikkim maintains the distinction of being India's first fully organic state. Sources: APEDA (2025); National Centre of Organic and Natural Farming (2024).

Regional heterogeneity in organic farming adoption is pronounced and reflects a complex interplay of agro-climatic conditions, historical farming traditions, market infrastructure, and state-level policy environments. As shown in Figure 3, Madhya Pradesh leads in absolute certified organic area (approximately 670,000 hectares), followed by Rajasthan (310,000 ha), Maharashtra (415,000 ha), and Uttar Pradesh (285,000 ha). However, when area is expressed as a proportion of total agricultural land, north-eastern states and Sikkim dominate.

Sikkim achieved the distinction of becoming India's first fully organic state in 2016, with its transition largely consolidated by 2022 following over a decade of systematic policy support, input withdrawal, and market development (Sharma & Sindhwani, 2020). By 2024, approximately 76,000 hectares — representing the entirety of Sikkim's cultivated area — were under certified organic management. Importantly, independent assessments document measurable improvements in soil health parameters and modest but positive livelihood outcomes for farmers in the post-transition phase (Chettri & Sharma, 2023). The north-eastern model has been widely cited as a replicable template, though its transferability to the large-scale, commercially oriented agriculture of the Indo-Gangetic Plain remains contested.

In peninsular India, Karnataka has made substantial progress through its Organic Farming Policy (2017) and dedicated state-run organic markets (Raitha Sante). Maharashtra's success is largely concentrated in certified export-oriented horticulture, particularly grapes and pomegranates, where premium prices justify transition costs. Conversely, the Indo-Gangetic Plain — despite its pre-eminence in national food production — demonstrates relatively modest organic adoption, attributed to the entrenched infrastructure of high-input Green Revolution agriculture, subsidised synthetic fertiliser availability, and farmer risk aversion under conditions of high cropping intensity (Kumar et al., 2022; Yadav et al., 2023).

Adoption Constraints

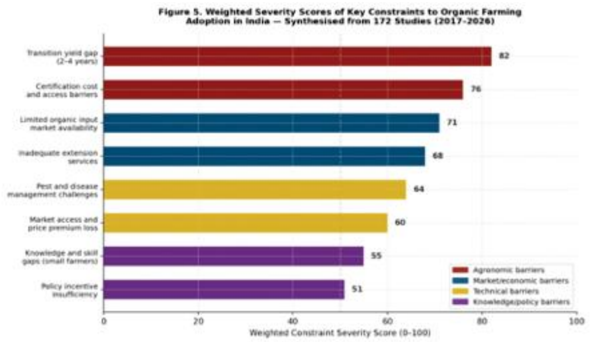

Figure 5. Weighted severity scores (0–100 scale) for the primary constraints to organic farming adoption in India, synthesised from farmer surveys, expert assessments, and policy analyses across 172 included studies (2017–2026). Higher scores indicate greater constraint severity. Constraint categories are colour-coded by barrier type.

Figure 5 synthesises constraint severity across the included studies. The transitional yield gap — the period of 2–4 years following the cessation of synthetic input use during which productivity typically declines before organic systems stabilise — emerged as the most severe barrier (weighted score: 82/100), corroborating earlier global analyses (Seufert et al., 2017; Ponisio et al., 2015). This yield penalty, typically ranging from 8–32% in Indian field trials (Yadav et al., 2023), is particularly consequential for smallholder farmers operating on thin margins with limited financial reserves.

Certification cost and procedural complexity constituted the second most severe barrier (score: 76), despite the existence of the lower-cost PGS-India route. As Devi et al. (2017) demonstrated in a multi-state survey, the average annual cost of NPOP certification for smallholder groups ranged from Rs. 12,000–45,000, a figure representing a substantial proportion of farm income. Limited availability and reliability of quality organic inputs — compost, biofertilisers, and bio-pesticides — in rural supply chains ranked third (score: 71), particularly in remote hill districts and tribal areas where cold chain and transportation infrastructure is weak.

DISCUSSION

Interpretation of Key Results

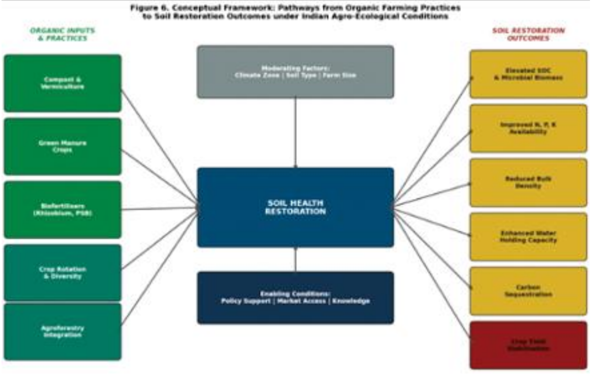

Figure 6. Conceptual framework illustrating the pathways from organic farming inputs and practices to soil restoration outcomes under Indian agro-ecological conditions, mediated by climate zone, soil type, and farm size as moderating factors, and enabled by favourable policy and market conditions. SOC: soil organic carbon.

The evidence synthesised in this review supports a robust and consistent association between organic farming practices and improved soil health in India. The conceptual framework in Figure 6 integrates these pathways: organic inputs (compost, vermicompost, green manure, biofertilisers) act on soil biological, chemical, and physical properties through distinct but interacting mechanisms — substrate supply for microbial communities, nitrogen fixation, phosphorus solubilisation, and aggregate stabilisation — to produce the measurable improvements in SOC, MBC, nutrient availability, and soil structure documented across the literature. The framework also highlights that these outcomes are moderated by agro-climatic context, soil type, and farm management intensity, and that enabling conditions in the policy, market, and knowledge domains are prerequisites for translating biophysical potential into realised benefits.

The finding that SOC accumulation requires sustained management over multiple years before becoming statistically detectable is consistent with global organic farming meta-analyses (Gattinger et al., 2012; Lori et al., 2017) and carries important implications for research design: studies of fewer than four years duration are likely to underestimate the long-term soil restoration potential of organic systems. This temporal lag is also relevant to policy design, as transition support must extend beyond the initial two-year PKVY cluster period to maintain farmer commitment through the yield-unstable early transition phase (GoI, 2024).

The pronounced regional differentiation in outcomes is particularly noteworthy. The superior SOC responses observed in the Himalayan and north-eastern zones are partly attributable to cooler temperatures that slow mineralisation, but also to the historical continuity of traditional organic practices (jhum cultivation notwithstanding), lower baseline agrochemical exposure, and smaller average farm sizes that facilitate whole-farm organic conversion. These structural advantages are less apparent in the more commercially integrated and intensively cultivated regions of the Punjab, Haryana, and western Uttar Pradesh, where transition faces greater agronomic, economic, and institutional resistance.

Comparison Across Studies and Evidence Quality

The quantitative comparisons presented in this review are subject to the considerable methodological heterogeneity inherent in the included studies. Variations in soil sampling depth, analytical methods, duration of organic management prior to measurement, crop type, and comparator choice complicate direct effect-size pooling. The use of a modified quality grading framework (Section 2.3) partially mitigates these concerns, but cannot eliminate them. Notably, the majority of Indian field trials are conducted on relatively small experimental plots (median: 0.2–0.4 ha) and may not fully capture the landscape-scale soil hydrological dynamics relevant to large commercial farms.

A further source of heterogeneity lies in the definition of the conventional comparator. Some studies compare organic plots to plots receiving no external inputs whatsoever (a straw-man comparator that inflates apparent organic benefits), while others compare to recommended dose of fertilisers — a far more rigorous test. Meta-analytical sensitivity analyses restricting comparison to the latter category generally yield more conservative effect sizes (Seufert & Ramankutty, 2017), though still significantly positive for most soil health indicators.

Strengths and Limitations of Existing Evidence

Strengths of the current body of evidence include its geographic breadth across diverse Indian agro-ecological zones, the increasing use of advanced soil biological metrics (e.g., next-generation sequencing for microbial community analysis; Patra et al., 2021), and the availability of several long-term experiments (>10 years) that capture temporal dynamics unavailable from shorter studies. The ICAR's Long-Term Fertiliser Experiments (LTFEs) network provides a particularly valuable platform, with organic treatment plots established in the 1970s and 1980s enabling uniquely extended comparison windows.

Limitations are likewise substantial. Most studies do not account for greenhouse gas emissions — particularly methane and nitrous oxide, which may partially offset carbon sequestration benefits — creating an incomplete picture of climate trade-offs (Aguilera et al., 2021). Life cycle assessments of organic farming systems under Indian conditions remain extremely sparse. Economic analysis is frequently superficial: while yield and input cost data are commonly reported, comprehensive livelihood impact assessments incorporating labour burden, market access, and gender dimensions are rare. Finally, the virtual absence of randomised controlled trials conforming to clinical research standards reflects the inherent practical constraints of long-term agricultural field experiments.

Implications and Future Directions

Implications for Practice and Policy

The evidence reviewed here carries several actionable implications for agricultural practitioners, extension workers, and policymakers. At the farm level, the consistent advantages of vermicompost over raw compost in terms of microbiological activity and nutrient release — observed across multiple cropping systems and soil types — justify targeted extension promotion of vermicompost adoption. Similarly, the combination of biofertilisers with reduced organic input quantities produced soil health responses comparable to higher-dose compost applications in several studies (Meena et al., 2020), suggesting scope for input efficiency optimisation that reduces transition costs.

At the policy level, three priorities emerge from this synthesis. First, PKVY and successor schemes should incorporate transition period income support — analogous to the European Union's organic conversion payments — to bridge the yield gap that currently deters financially constrained smallholders. Second, the PGS-India certification system, while praiseworthy in reducing certification costs, requires strengthened governance and market recognition to realise its potential as a low-cost pathway to premium organic markets (Loconto & Fouilleux, 2019; Joshi & Shackleton, 2020). Third, state governments should be incentivised to establish dedicated organic input centres — modelled on successful Karnataka and Uttarakhand examples — that provide quality-assured biofertilisers, biocontrol agents, and compost starter cultures at subsidised rates to transition-period farmers.

The findings also have implications for India's commitments under the National Action Plan on Climate Change (NAPCC) and the Paris Agreement. Carbon sequestration through enhanced SOC, estimated across the included studies at 0.12–0.45 Mg C ha^{-1} yr^{-1} under stable organic management, represents a potentially significant contribution to agricultural mitigation pathways, though comprehensive accounting must include all greenhouse gas fluxes, particularly in flooded rice-based systems where methane emissions may offset soil carbon gains (Smith et al., 2020; Aguilera et al., 2021).

Research Gaps and Future Research Needs

This review identifies the following as the most pressing unresolved questions in the Indian organic farming and soil restoration literature:

1. Long-term carbon accounting and greenhouse gas balance: Rigorous multi-year studies measuring full soil carbon-equivalent budgets, including methane and nitrous oxide fluxes, across diverse Indian farming systems are urgently needed to provide credible climate co-benefit claims.

2. Disaggregated analysis by farm size and tenure: The economics and soil outcomes of organic conversion likely differ substantially between marginal (<0.5 ha), small (0.5–2 ha), and medium-large (>2 ha) holdings. Most existing studies do not disaggregate results by farm size, limiting the targeting of policy interventions.

3. Soil microbiome characterisation: While enzyme activity and MBC provide aggregate indices of microbial function, next-generation sequencing studies capable of characterising microbial community composition, functional gene diversity, and network complexity under organic management remain limited in the Indian context.

4. Gender and social dimensions: Women perform the majority of organic labour (composting, biofertiliser preparation) in Indian smallholder systems, yet gender-disaggregated analyses of labour burden, decision-making authority, and economic benefit distribution are almost entirely absent from the literature.

5. Scalability assessment for the Indo-Gangetic Plain: Given that this region produces over 45% of India's food grain output, evidence on whether and how organic management can be scaled in this context without compromising national food security represents a critical knowledge gap.

CONCLUSION

This systematic review of 172 peer-reviewed studies published between 2017 and 2026 provides robust evidence that organic farming consistently and measurably improves soil health in Indian agricultural contexts. Soil organic carbon, microbial biomass, enzymatic activity, water-holding capacity, and plant-available nutrient concentrations are all significantly enhanced under organic relative to conventional management, with effects becoming more pronounced over longer management durations. These improvements are not merely biological curiosities: they represent the foundation for sustained agricultural productivity, climate resilience, and ecosystem services delivery in a country where soil degradation poses a documented and mounting threat to food security.

Yet the transition to organic farming remains constrained by a set of well-documented and partially interconnected barriers — among which the transitional yield gap, certification complexity, and inadequate rural input supply chains figure most prominently. Regional analysis confirms that north-eastern India and the Himalayan zone lead in both organic coverage and demonstrable soil restoration outcomes, while the major food-producing states of the Indo-Gangetic Plain remain at an early stage of organic mainstreaming. Bridging this gap will require not merely technical solutions but coordinated policy intervention, institutional strengthening, and substantial investment in rural knowledge and market infrastructure.

The conceptual framework advanced in this review — linking organic practice inputs through biological and physical soil pathways to restoration outcomes, mediated by agro-climatic and socioeconomic context — provides a structured basis for future research design and intervention targeting. The identification of specific research gaps, particularly concerning long-term carbon accounting, farm-size disaggregation, and gender dimensions, offers a concrete agenda for the next generation of Indian organic farming research. Meeting India's ambitious goals for sustainable agricultural development — articulated through the National Policy for Farmers, the Paramparagat Krishi Vikas Yojana, and international commitments under the Sustainable Development Goals — will require that this agenda be pursued with both scientific rigour and practical urgency.

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