Organic Farming Practices and their Impact on Soil Health: Advancing Environmental Sustainability in India A Systematic Literature Review

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Abstract: Soil health, an indicator of agricultural productivity and environmental sustainability is measured by physical, chemical and biological properties. Although chemical fertilizers-based conventional farming has shown to increase crop yield, it negatively affects the soil health. Organic farming, on the other hand, is associated with increased soil organic matter and improved soil structure. Such soil not only fosters crop yield but also supports environmental sustainability by sequestering carbon, reducing soil erosion and preserving biodiversity. This systematic literature review was conducted to evaluate existing research on the impact of organic farming practices on soil health in India, focusing on their effectiveness in enhancing environmental sustainability. Multiple search strategies were employed across well-known databases. Relevant publications were selected using pre-established selection criteria, resulting in 23 selected studies that address the research questions. Findings identified application of organic inputs (manures, compost, biofertilizers), crop rotation, residue management and conservation agriculture as organic farming methods employed across India. These practices are effective in significantly enhancing organic matter, microbial population, biochemical processes, water retention capacity and nutrient levels of soils. While the benefits of organic farming are evident, its limited adoption calls for increased policy support from the government and farmer education to meet the Sustainable Development Goals.

Keywords: Environmental sustainability, India, organic agriculture, organic farming, soil health, soil quality

Introduction

Soil is a vital ecosystem that acts as the foundation for life on Earth and sustains living organisms (Muhie, 2022; Rusdiyana et al., 2024). According to the Intergovernmental Technical Panel on Soils (ITPS), soil health is currently defined as the "ability of the soil to sustain productivity, diversity and environmental services of terrestrial ecosystems" (Khangura et al., 2023; Rusdiyana et al., 2024). It encompasses physico-chemical and biological properties, including nutrient levels, soil structure, pH, organic matter content, microbial activity etc. (Chaudhry et al., 2024). By using these indices, quality of soil can be assessed to understand its suitability for agriculture and adopt appropriate farming practices to improve soil health (Gelaw et al., 2015).

Chemical fertilizers have been extensively utilized since the onset of "Green Revolution" (Bhanuvally et al., 2024). By providing essential nutrients such as nitrogen, phosphorus and potassium, it enhances crop yields and increase agricultural productivity in the short term. However, imbalanced application of such inorganic chemicals for prolonged period has led to soil degradation, poor soil structure, decreased organic matter and reduced microbial diversity (Figure 1). This deterioration negatively affects plant growth and food production. In addition, the application of harmful pesticides in farming poses significant health risks, causing both acute and chronic conditions in humans (Damalas & Koutroubas, 2016). Consequently, chemical-based conventional farming places a heavy burden on soil, plants and animals, raising critical concerns about its impact on the entire ecosystem (Nicolopoulou-Stamati et al., 2016).

To address these problems, organic farming represents one of the alternatives for sustainable agriculture (Lee et al., 2015; Mishra et al., 2019). Unlike in conventional farming methods, natural inputs (such as manure, composts, biofertilizers) derived from plant and animal wastes are used instead of chemical pesticides and synthetic fertilizers in organic farming for crop production while enhancing soil diversity and protecting the environment (Mishra et al., 2019). Through organic agriculture, soil properties are improved by increasing microbial diversity thriving beneath the surface and promoting their activities (Babu et al., 2020; Yadav et al., 2021). This type of farming is associated with increased soil organic matter and improved soil structure (Figure 1). Such soil not only fosters crop yield but also protects the environment by sequestering carbon, reducing soil erosion and preserving biodiversity (Smith et al., 2019). In India, where agriculture forms the backbone of the economy, organic farming practices are being prioritized nowadays to promote environmental conservation and long-term food security (Sahu et al., 2024; Sarkar et al., 2024).

Despite the growing interest in organic farming, there is a need to systematically analyse the diverse methods adopted by farmers across India and assess their impact on soil health and environmental outcomes. This systematic literature review (SLR) addresses this gap by providing a comprehensive examination of organic farming practices in India. It aims to identify and categorize the different organic farming methods adopted by farmers across India and evaluate their effectiveness in improving soil health and environmental sustainability.

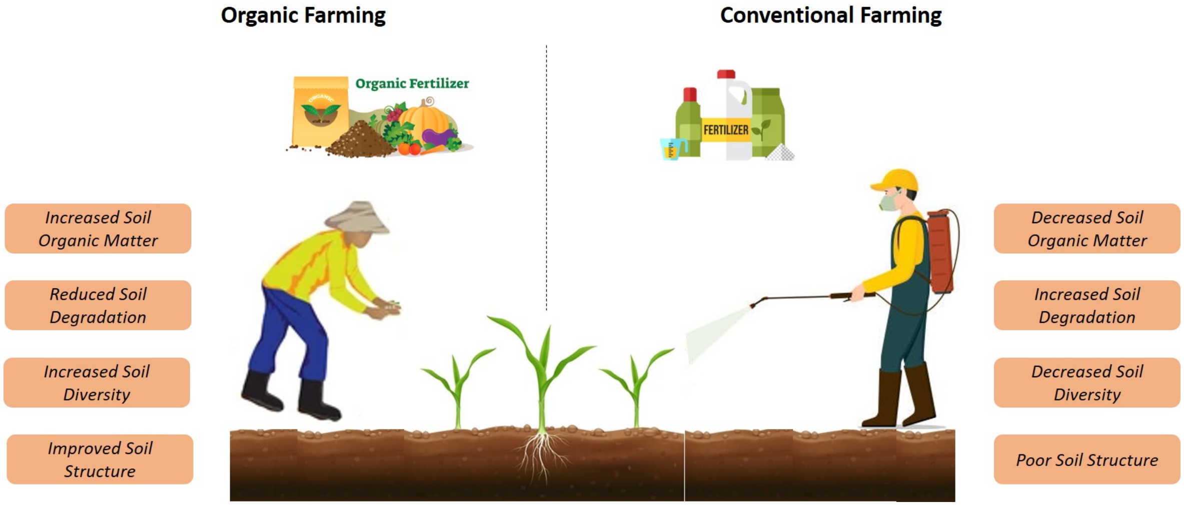

Figure 1: Organic farming versus conventional farming and soil health

Research Methodology

To perform this systematic review, the preferred reporting items for systematic reviews and meta-analyses (PRISMA) procedures and checklist (Moher et al., 2010) were followed.

Research question

This present paper was designed to address the following research question:

How do organic farming practices contribute to improving soil health and promoting environmental sustainability in India?

Hypothesis

The present paper formulated the following research hypothesis to address the research question:

H1: *Organic farming practices have a positive impact on soil health, contributing significantly to advancing environmental sustainability in India.*

Selection criteria

Publications that met the following criteria were included: (1) Studies addressing environmental sustainability in terms of soil health; (2) Studies conducted in India; (3) Published articles in peer-reviewed journals; and (4) Studies written in English between 2014 and 2024.

Publications that met the following criteria were excluded: (1) Studies focusing on economic or social implications of organic farming; (2) Studies such as reviews, book chapter, editorials, conference papers and government reports; (3); Studies published in languages other than English; and (4) Studies that have not granted access.

Search strategy

Based on previous studies concerning the soil health in organic farming, various meaningful keywords were identified for use as search terms to retrieve papers relevant to the topic. These included “organic agriculture”, “organic farming”, “organic agricultural practices”, “organic farmers practice”, “organic food production”, “sustainable farming practices”, “ecological farming method”, “environmental sustainability”, “sustainable environment”, “environmental implication”, “soil health”, “soil erosion”, “soil quality”, “soil properties” and “India”. Literatures were searched in three electronic databases - Science Direct, Springer Link and Google Scholar. Logical combinations of appropriate keywords were employed during the search process using operators “AND” and “OR” within article title, abstract and keywords, yielding 571 articles (Table 1). Additionally, relevant studies were manually searched within the identified studies and related review papers. Table S1 provides details of the electronic databases used, search terms, filters and number of results retrieved.

Table 1: Databases and number of hits

Databases	Number of hits
Science Direct	238
Springer Link	325
Google Scholar	8
Total	**571**

PRISMA protocol

The PRISMA guidelines were followed to facilitate the identification, selection, evaluation and synthesis of studies relevant to the above-mentioned research questions (Figure 2). Initially, articles were searched in three electronic databases using the search terms and a total of 571 articles (Science Direct – 238, IEEE – Springer Link - 325 and Google Scholar - 8) were identified. In the second step, duplicates were removed yielding 495 articles which were reviewed to obtain good quality literatures. Based on abstract, articles which were found non-relevant were excluded, resulting in 64 articles. In the next step, these articles were screened and those which did not fit for pre-established selection criteria were removed. Screening of titles and abstracts based on the selection criteria was done independently by two reviewers. Disagreements were resolved through discussion and after consulting a third reviewer. Articles published in other languages were removed, as English is considered as a universal language in research field. The review process was further narrowed down to research articles that were downloaded as full-text, published in peer-reviewed journals between 2014 and 2024. This has resulted in a total of 23 manuscripts which were included in the qualitative analysis. The researcher then manually assessed these articles. The references of the selected studies were then chronologically entered into an Excel spreadsheet for organization and analysis.

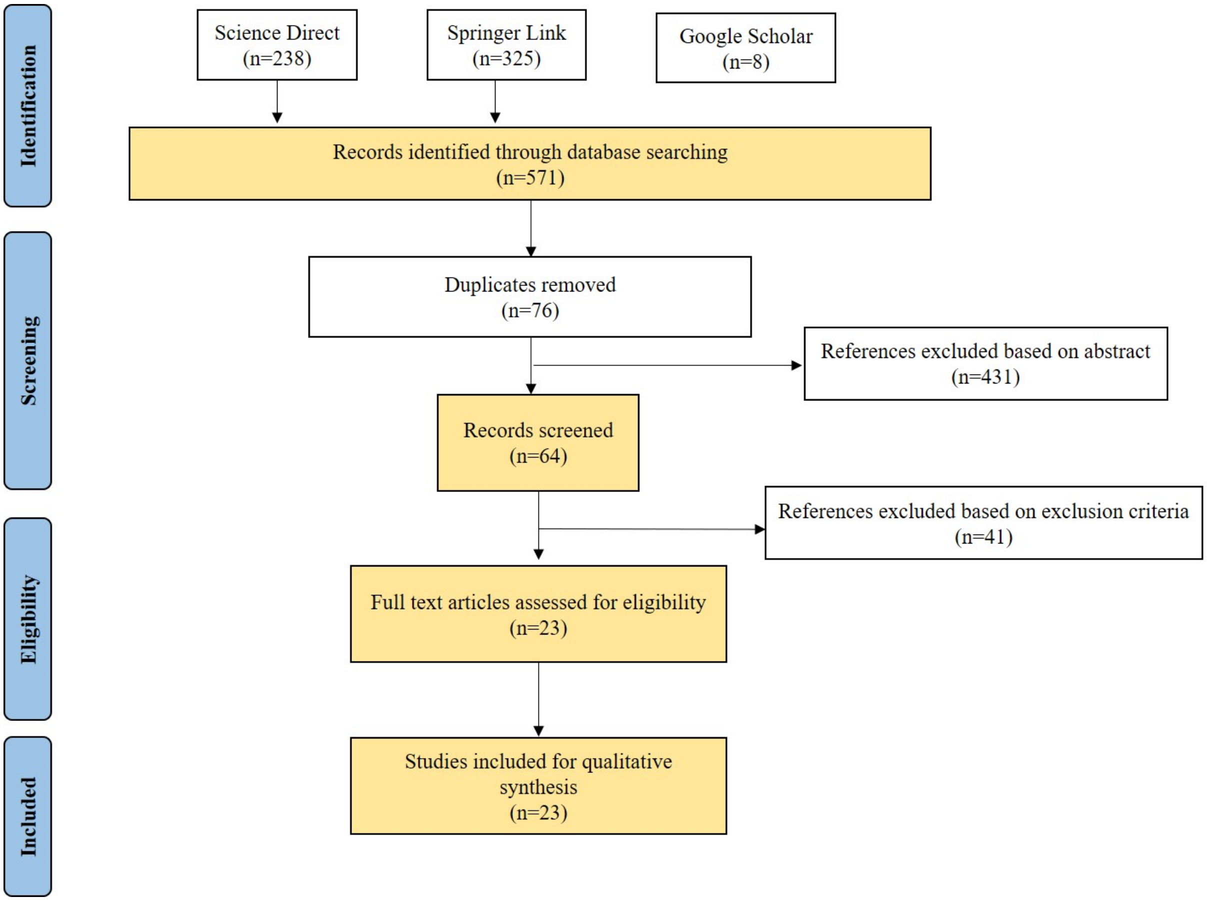

Figure 2: PRISMA protocol

Data extraction and analysis

From each of the included studies, various information was extracted such as year of publication, name of Indian states from where the experiment was carried out, organic farming methods and soil biological (organic matter, microbial population, microbial biomass carbon, enzymatic activity), chemical (pH, electrical conductivity, nutrient level, organic carbon) and physical (moisture content, water holding capacity, bulk density, aggregate stability, porosity, penetration resistance, water infiltration) properties. The extracted data included in this study are presented in tabular form and through descriptive statistics. Following the data extraction process, a qualitative analysis of the extracted data was conducted.

Results

Bias assessment

To mitigate the internal biases of third-party sources in this systematic literature review, several strategies were employed to evaluate the impact of organic farming on soil health in India. First, a comprehensive and systematic selection process was followed using PRISMA guidelines, where studies from multiple disciplines (such as agriculture, environmental science, and soil microbiology) were incorporated to minimize selection bias. Additionally, studies were selected based on predefined inclusion and exclusion criteria, rather than subjective preferences, to ensure an unbiased selection process. Secondly, to address confirmation bias, studies reporting both positive and negative results as well as neutral effects of organic farming were critically analysed. Thirdly, methodological biases were accounted for by comparing different research designs, sample sizes, and techniques, ensuring reliability across findings. Finally, regional biases were minimized by including studies from different regions of India which helped to capture various soil types, climatic conditions, farming practices and soil health dynamics.

Overview of selected publications

Organic farming plays a pivotal role in improving soil quality, maintaining its health and promoting environmental sustainability, which is reflected in the research landscape that has steadily evolved over the years. Figure 2 demonstrates a consistent increase in scholarly output from 2014 to 2018, marking a period of growing academic interest in sustainable agriculture. The period between 2020 and 2021 witnessed a substantial surge in publications which can be linked to heightened global discussions on climate change and the essential role of sustainable practices in mitigating its effects. The most substantial growth was observed in 2024, with five studies published, representing the highest annual research output within this timeframe. Factors driving this peak include advancements in agricultural research methodologies, policy support for organic farming and increasing recognition of the long-term benefits of sustainable practices in India.

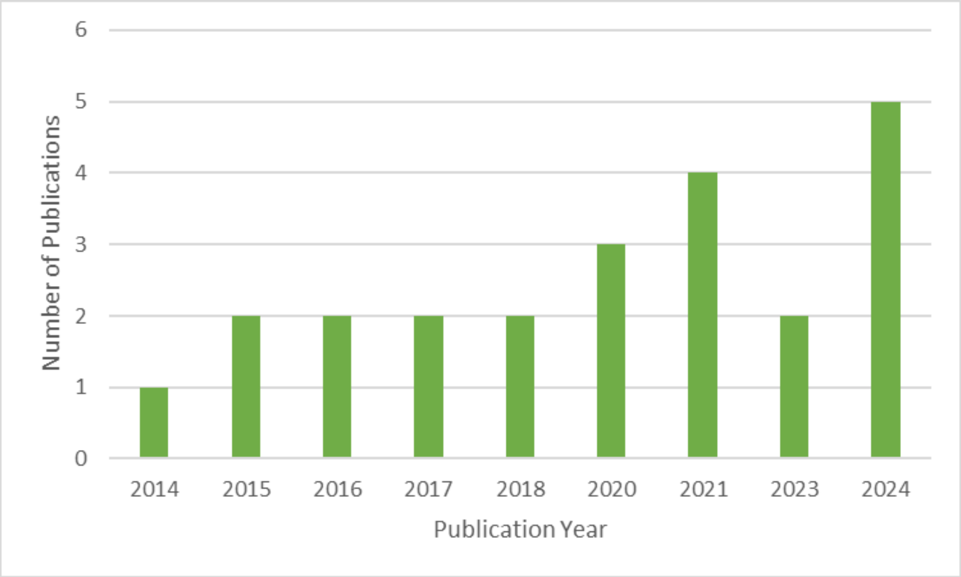

Figure 3: Time distribution of selected papers

Figure 4 illustrates the distribution of studies on organic farming practices and their impact on soil health across various Indian states, reflecting the geographic focus of the reviewed literature. The data highlights a diverse representation, with some states showing a higher concentration of research efforts. Madhya Pradesh (n = 6) emerges as a significant focus area, likely due to its extensive agricultural landscape and the prominence of organic farming initiatives in the region. This is followed by Sikkim (n = 3), New Delhi (n = 3) and Uttarakhand (n = 3), reflecting their active engagement in sustainable agricultural practices. The contributions from other states indicate a growing nationwide interest in expoloring organic farming practices.

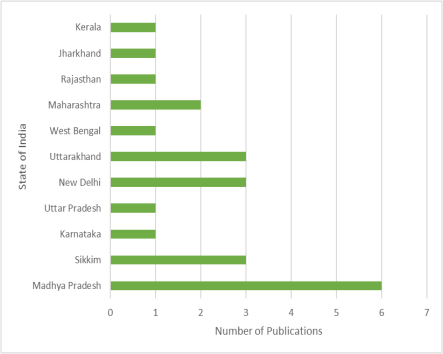

Figure 4: Geographical distribution of selected papers

Types of organic farming practices employed

Various organic farming practices aim to enhance soil fertility and sustainable farming (Table 1). Integrated organic nutrient management practices often relies on varied organic inputs to optimise soil health. Treatments using 50% and 100% farmyard manure (FYM) were investigated by (Biswas et al., 2023), while FYM and vermicompost (VC) were incorporated by (Babu et al., 2020). (Aher et al., 2015) utilized neem oil, rock phosphate and cattle dung manure. (Thangasamy et al., 2017) explored treatments including neem cake, VC, poultry manure and FYM, whereas (Bhat et al., 2017) used FYM, rock phosphate, castor cake and compost. (Yadav et al., 2021) tested 12 combinations of green-leaf manure, compost, VC, FYM and their mixtures in varying proportions. (Mukherjee et al., 2024) combined Jeevamrit, biochar (BC), VC and FYM for nutrient management, while (Paul et al., 2016) introduced combinations of microbial consortia, VC, chicken manure and FYM. Similarly, (Srinivasan et al., 2016) proposed organic nutrient management (ONM) with biofertilizers, VC, ash, neem cake and FYM. (Bhosale et al., 2015) analysed treatments involving varying proportions of VC, pressmud and soil. (Schweizer et al., 2022) explored biodynamic (BIODYN) and bioorganic (BIOORG) systems using composted manure, demonstrating their long-term benefits.

Practices such as residue management and crop rotation (Meena et al., 2020; Schweizer et al., 2022; Yadav et al., 2021), incorporating varied cropping patterns (Singh et al., 2021) and tillage methods (Babu et al., 2023) alongside organic mulching techniques, were emphasised as effective in-situ strategies for conserving soil moisture organically (Singh et al., 2021). Rathore (2024) investigated diversified tillage and cropping systems under conservation agriculture (CA) and integrated organic management (IOM). (Dongre et al., 2018) conducted duration-based studies, comparing soil properties across organic farming periods of less than three years, three to five years and over five years.

Studies by (Srinivasan et al., 2016) and (Dubey et al., 2014) compared the effects of 100% organic, 100% inorganic and integrated nutrient management (INM) approaches on soil health. (Kaje et al., 2018) evaluated unfertilized control, conventional management and five organic treatments including FYM, Sesbania green manure, blue-green algae and *Azotobacter* in rice-wheat systems. Collectively, these approaches underscore the multifaceted approaches to sustainable organic farming.

Table 1: Types of organic farming methods practiced across India

Organic farming methods		Geographical location	References
Integrated organic management	farmyard manure	Varanasi	(Biswas et al., 2023)
	farmyard manure, vermicompost	Sikkim	(Babu et al., 2020)
	neem oil, rock phosphate, cattle dung manure	Bhopal	(Aher et al., 2015)
	neem cake, vermicompost, poultry manure, farmyard manure	Maharashtra	(Thangasamy et al., 2017)
	Farmyard manure, rock phosphate, castor cake, compost	Madhya Pradesh	(Bhat et al., 2017)
	green-leaf manure, compost, vermicompost, farmyard manure	Rajasthan	(Yadav et al., 2021)
	Jeevamrit, biochar, vermicompost, farmyard manure	Jharkhand	(Mukherjee et al., 2024)
	microbial consortia, vermicompost, chicken manure, farmyard manure	Uttarakhand	(Paul et al., 2016)
	biofertilizers, vermicompost, ash, neem cake, farmyard manure	Kerala	(Srinivasan et al., 2016)
	Farmyard, biofertilizers	Madhya Pradesh	(Dongre et al., 2018)
	Farmyard, vermicompost, crop residue, biofertilizers	New Delhi	(Meena et al., 2020)
	composted manure	Madhya Pradesh	(Schweizer et al., 2022)
	Farmyard manure, SGM, LGLM, BGA, Azotobacter	New Delhi	(Kaje et al., 2018)

Organic farming methods		Geographical location	References
	Farmyard manure, green manure pressmud, which is enriched with feather degraded product and humus	New Delhi Maharashtra	(Rathore et al., 2024) Bhosale et al. 2015
Residue management	- -	Madhya Pradesh Bhopal	Schweizer et al., 2022 (Yadav et al., 2021)
Diverse cropping system	Maize-fallow, maize + cowpea-rapeseed (toria), maize + cowpea-buckwheat, maize + cowpea-barley, maize + cowpea-garden pea, maize + cowpea-rajmash	Sikkim	(Singh et al., 2021)
	Maize-mustard (M-Mus), maize + cowpea-mustard (M + C-Mus), pigeon pea-wheat (PP-W)	New Delhi	(Rathore et al., 2024)
	Maize–black gram (Vigna mungo var. Viridis)–toria, maize–black gram–buckwheat, maize–rajmash (Phaseolus vulgaris)–toria, maize–rajmash–buckwheat	Sikkim	(Babu et al., 2023)
Soil moisture conservation practices	No-mulch, maize stover mulch, maize stover + weed biomass mulch	Sikkim	(Singh et al., 2021)
Tillage systems	conventional tilling, reduced tilling, zero tilling	Sikkim	(Babu et al., 2023)
Integrated nutrient management	Organic and inorganic 50% organics + 50% inorganics	Kerala Madhya Pradesh	(Srinivasan et al., 2016) (Dubey et al., 2014)

Impacts of organic farming on soil health

Biological soil health

Soil organic matter

Soil organic matter (SOM) is substantially influenced by organic farming. Sahu et al. (2024) reported SOM levels of 1.13% in organic farming systems compared to 0.66% in inorganic systems, though the variations was not statistically substantial. Bhosale et al. (2015) emphasised the impact of organic amendments by demonstrating a significant increase in SOM to 16.6% when pressmud was incorporated at 20% of the soil composition. Additionally, Yadav et al. (2021) provided long-term evidence of organic practices' benefits, recording a 96% increase in SOM over five years with consistent crop residue retention at 90%.

Enzymatic activity

The positive effects of organic farming on soil enzymatic activity are well-documented, emphasising its influence on critical biochemical processes. Aher et al. (2015) highlighted the superior performance of organic farming systems, with significantly higher dehydrogenase activity (DHA) (98.2 µg TPF g^{-1} day^{-1}) and alkaline phosphatase (ALP) activities (178.2 µg PNP g^{-1} 12 hr^{-1}) compared to chemical and integrated systems. Babu et al. (2020) observed maximal fluorescein diacetate (67.1 µg FDA g^{-1} soil h^{-1}) and DHA (22.1 µg TPF g^{-1} soil h^{-1}) in soils treated with a combination of FYM (6 t ha^{-1}) and VC (2 t ha^{-1}), while maximum acid phosphatase activity (ACP) was found in soil treated with VC (4 t ha^{-1}). Biswas et al. (2023) further reported substantial enzymatic activities, particularly ACP (369 µg pNP g^{-1} h^{-1}) and fluorescein diacetate hydrolase (14.6 µg fluorescein g^{-1} h^{-1}) under 100% FYM application. Yadav et al. (2021) corroborated these findings by reporting peak DHA (12.46 µg TPF g^{-1} soil/ha) and ALP (12.53 µg PNP g^{-1} soil/ha) activities under 100% VC treatments. Sarkar et al. (2024) highlighted the peak DHA activity (3.45 µg TPF g^{-1} oven-dry soil/24 h) achieved through an integrated approach to organic and natural nutrient management. Similarly, Rathore et al. (2024) reported significantly higher DHA activity at both the upper (0–15 cm) and deeper (15–30 cm) soil layers, with values of 73.11 and 50.5 μg TPF g^{-1} day^{-1}, respectively. The study also reported higher ALP (5.9 and 5.12 mg g^{-1} h^{-1}) and urease (43.27 and 38.32 μg NH3-N hr^{-1}) activities under integrated organic management in these soil layers. Babu et al. (2023) and Paul et al. (2016) supported the enhancement of DHA and phosphatase activities through organic and integrated nutrient management treatments, while (Srinivasan et al., 2016) identified increased activities of ACP (42.8 μmol pNP g^{-1}), urease (8.8 μmol NH_3-N g^{-1} h^{-1}) and DHA (193.0–205 nmol TPF g^{-1} soil h^{-1}) in these systems.

Based on cropping system, (Rathore et al., 2024) found elevated DHA activity in maize + cowpea-mustard system at both 0–15 (66.32 μg TPF g^{-1} day^{-1} at 0-15 cm) and 15–30 cm (38.83 μg TPF g^{-1} day^{-1} at 15-30 cm) soil depths under integrated organic management. Higher ALP activities were observed in this system with values of 4.27mg g^{-1} h^{-1} at the 0–15 cm layer and 3.62 mg g^{-1} h^{-1} at the 15-30 cm layer. However, the maize-mustard system exhibited higher urease activity at 15-30 cm (32.89 μg NH3-N hr^{-1}). (Singh et al., 2021) found increased DHA activity (16.43 μg TPF g^{-1} soil h^{-1}) in the maize + cowpea system. In addition, the application of maize stover and weed biomass mulch significantly increased DHA activity (14.99 μg TPF g^{-1} soil h^{-1}). Bhat et al. (2017) reported higher activities of DHA, beta-glucosidase, ACP and ALP in soils under seven years of organic management, particularly during key growth stages of soybean and wheat.

Soil microbial biomass carbon

Organic farming practices have been shown to significantly improve soil microbial biomass carbon (SMBC), which denotes microbial activity and soil organic content. (Biswas et al., 2023) observed the highest increase in SMBC (83.9%) with the use of 100% FYM in manure-based organic practices. (Babu et al., 2020) reported that addition of VC (2 t ha^{-1}) along with FYM (6 t ha^{-1}) resulted in 377.4 μg SMBC per gram soil. Similarly, (Paul et al., 2016) found that applying FYM at 25 t ha^{-1} with microbial consortia significantly enhanced SMBC (376.4 g g^{-1} soil) as compared to the control treatment (235.8 g g^{-1} soil).

Dongre et al. (2018) found that organic farming and diversion cropping systems used for over five years yielded the highest SMBC (262.36 mg kg^{-1} soil). (Rathore et al., 2024) observed that the maize + cowpea-mustard system achieved the highest SMBC (398.74 mg/kg at 0–15 cm and 357.15 mg/kg at 15–30 cm), whereas the pigeon pea-wheat system showed notable SMBC at 15–30 cm (359.48 mg kg^{-1}). Babu et al. (2023) found that the maize-black gram-buckwheat system produced maximum SMBC (354.8 μg g^{-1}), followed closely by the maize-rajmash-buckwheat system (353.0 μg g^{-1}).

Singh et al. (2021) examined soil moisture conservation practices and found that maize stover along with weed biomass mulch led to the highest SMBC (311.8 μg g^{-1} soil). (Babu et al., 2023) found that zero tillage resulted in a substantially higher SMBC (369.7 μg per gram soil) than both conventional and reduced tillage methods. Srinivasan et al. (2016) found that organic and integrated nutrient management systems exhibited notably higher SMBC levels than conventional systems. (Rathore et al., 2024) reported the highest SMBC values in integrated organic management, with 438.92 mg per kg at 0–15 cm and 394.61 mg per kg at 15–30 cm soil depths. Overall, these findings indicate that organic farming practices significantly enhance SMBC, contributing to improved soil health and fertility.

Soil microbial population

The usage of organic inputs has been consistently linked to a growth in soil microbial populations, including bacteria, fungi and actinomycetes. (Thangasamy et al., 2017) observed an enhancement in fungal populations under amendments of FYM (101.9%), followed by poultry manure (79.4%), VC (33.1%) and neem cake (23.1%), while the control treatment showed a population decline of 53.9–67.5%. (Mukherjee et al., 2024) found that when compared to control treatments, bacterial (122%) and fungal (58%) populations were boosted by combining 50% FYM, 50% vermicompost and biochar during all stages of onion growth. (Sarkar et al., 2024) reported the highest bacterial population (138×10^{11} CFU/g) using 100% organic inputs, while the integrated use of natural and organic treatments yielded substantial fungal loads (43.66×10^{3} cfu/g). The combined usage of organic, inorganic and natural inputs was associated with the highest population of actinomycetes (14.30×10^{6} cfu/g) in soils after harvest. (Yadav et al., 2021) found that 100% vermicompost application effectively resulted in achieving peak bacterial (65.25×10^{7} CFU per gram soil), fungal (25.94×10^{5} CFU per gram soil), and actinomycetes (27.91×10^{6} CFU per gram soil) populations 30 days after sowing. (Dubey et al., 2014) observed a pronounced growth of fungi, bacteria, azotobacter, phosphate-solubilising bacteria and actinomycetes, following the adoption of 100% organic nutrition after four crop cycles.

Integrated organic management (IOM) demonstrated the highest fungal (11.88 CFU × 10^{-3} per gram soil), bacteria (14.71 CFU × 10^{-5} per gram soil) and actinomycetes (8.36 CFU × 10^{-5} per gram soil) populations at 0-15 cm, demonstrating the benefits of organic farming practices (Rathore et al., 2024). In terms of cropping systems, the maize + cowpea-mustard system recorded the highest fungi (9.8 CFU ×10^{-3} per gram soil) and actinomycetes (7.4 CFU ×10^{-5} per gram soil) populations at 0-15 cm soil depth, whereas the maize-mustard system exhibited the highest bacterial populations (6.58 CFU ×10^{-5} per gram soil) at a depth of 15-30 cm. By quantifying 16S rDNA and *nifH* genes,

(Goel et al., 2020) found greater abundances of diazotrophs (8 × 10^6 in rice and 1.8 × 10^7 in wheat) and total bacteria (2.52 × 10^{11} in rice and 2.40 × 10^{11} in wheat) in organic farming systems. Overall, these studies underline the critical role of organic amendments in enhancing soil microbial populations, contributing to improved soil health and fertility.

Chemical soil health

Soil pH

The application of VC at 4 t ha^{-1} caused a significant increase in soil pH, raising it from 6.15 to 6.23 after five cropping cycles (Babu et al., 2020). Contrarily, FYM together with crop residue (CR) and biofertilizers (BF) decreased soil pH from 8.45 to 8.0 and 8.15 in cropping systems of rice-mungbean-wheat and rice-wheat cropping systems, respectively, after 12 years of organic farming practices (Meena et al., 2020). Comparable declines in pH were also observed in organic farms, with reductions of 0.32 and 1.1 units recorded at two different soil depths when compared to inorganic systems (Sahu et al., 2024). In mixed systems integrating inorganic, natural and organic components, a neutral pH of 6.92 was reported under fully organic treatments (Sarkar et al., 2024). Conversely, (Schweizer et al., 2022) observed slightly higher pH levels under organic systems in the top soil (8.3) compared to conventional systems (8.15), and a similar pattern observed in subsoil layers. However, no significant differences in pH were identified between organic and conventional management practices in soybean cultivation (Bhat et al., 2017). (Dongre et al., 2018) reported a negligible decline in soil pH due to organic matter application, whereas (Dubey et al., 2014) found that soil pH remained unchanged from its initial value. Residue-based organic treatments also had an impact on soil pH. (Yadav et al., 2021) observed minimal variations, with pH values remaining nearly neutral (7.7-7.9) under residue retention practices. This indicates that integrating crop residues may help buffer soil pH, enhance organic matter content and ultimately improve overall soil quality.

Soil electrical conductivity

A noteworthy reduction was observed in soil electrical conductivity (EC) under organic farming systems in three different studies. (Meena et al., 2020) observed a decline in EC over a period of 12 years when organic nutrient treatments were employed. (Sahu et al., 2024) recorded lower EC values in organic farms (0.24 dS/m) compared to those in inorganic farms (0.54 dS/m). Similarly, (Yadav et al., 2021) reported a substantial decrease in EC associated with the adoption of 90% residue retention practices. (Sarkar et al., 2024) achieved lowest EC value (0.200 dS/m) through a combination of natural, organic and inorganic treatments, highlighting the importance of nutrient source diversification in regulating EC levels. Contrastingly, studies by (Dongre et al., 2018), (Paul et al., 2016) and (Dubey et al., 2014) reported that organic farming methods did not result in measurable differences in EC when compared to conventional farming, suggesting that organic practices neither significantly reduce EC nor contribute to increased salinity.

Soil nutrient level

Organic farming practices have been evidenced to enhance soil nutrient levels when compared to conventional and integrated farming systems (Aher et al., 2015). The integrated usage of FYM (6 t ha^{-1}) and VC (2 t ha^{-1}) yielded the maximal soil available nitrogen levels (390 kg ha^{-1}) (Babu et al., 2020). (Bhat et al., 2017) observed phosphorus availability of 5.9 µg/gm in soils treated with a mixture of farmyard manure, rock phosphate, castor cake and compost. (Dubey et al., 2014) found that the application of 100% organic treatments not only sustained phosphorus and potassium availability but also improved nitrogen levels after four cropping cycles. However, (Sahu et al., 2024) reported higher levels of nitrogen, phosphorus and potassium in organic farms; however, the variations were not consistently statistically substantial. In a study by (Meena et al., 2020), the integration of BF, CR and VC increased nitrogen availability from 210 to 245 kg ha^{-1} in basmati rice-wheat-mungbean systems and from 203 to 243 kg ha^{-1} in rice-wheat systems. (Bhosale et al., 2015) identified the highest concentrations of potassium (0.17%), phosphorus (0.58%) and nitrogen (0.33%) in soils amended with foliar FDP and pressmud. (Mukherjee et al., 2024) emphasised that applying a mixture of 50% FYM, 50% VC and BC at 500 kg ha^{-1} caused substantially greater nutrient availability with nitrogen, phosphorus and potassium increasing by 21%, 103% and 21%, respectively, compared to other treatments. (Biswas et al., 2023) reported that the continuous combined usage of organic and inorganic fertilizers was found to significantly improve the availability of both micro-nutrients (Zn, Cu, Fe, Mn, B) and macro-nutrients (P, K, S). (Sarkar et al., 2024) found that integrating natural and organic inputs resulted in the highest quantity of phosphorus (44.38 mg/kg) and nitrogen (286 mg/kg), through potassium levels were the lowest (103 mg/kg) in systems relying solely on organic practices. (Paul et al., 2016) indicated that applying FYM at 10 t ha^{-1} in conjunction with chemical fertilizers and microbial consortia led to a marked increase in soil N, P and K levels. (Srinivasan et al., 2016) reported that INM systems, involving FYM (20 t ha^{-3}), inorganic fertilizers and phosphorus-solubilizing bacteria, increased nutrient availability by 8.24%.

Prolonged residue retention significantly enriched nutrient levels in black soil (Yadav et al., 2021). Retaining 90% of soybean residues over five years increased nitrogen (197.3 kg), phosphorus (32.4 kg) and potassium (89.7 kg). Meanwhile, wheat residue retention at the same time contributed 85.7 kg of N, 15.3 kg of P and 232.2 kg of K. (Singh et al., 2021) reported that soils treated with maize stover and weed biomass mulch achieved the highest availability of nitrogen (357.9 kg ha^{-1}) and potassium (372.4 kg ha^{-1}).

Soil organic carbon

Studies have found that in comparison to conventional and integrated farming practices, soil organic carbon (SOC) levels are significantly improved by organic farming methods (Aher et al., 2015; Goel et al., 2020; Srinivasan et al., 2016). SOC improvements ranging from 0.55% to 1.30% were observed with the usage of organic manures (Dongre et al., 2018). The usage of FYM at 12 t ha^{-1} led to a 1.52% increase in SOC (Babu et al., 2020) whereas a combination of neem cake, VC, poultry manure and FYM resulted in SOC enhancements ranging from 10.3% to 19.4% compared to control treatments (Thangasamy et al., 2017). Treatments that included 50% FYM, 50% VC and biochar at a rate of 500 kg h^{-1} produced 43% higher SOC levels than control treatments and 19% greater than other combinations (Mukherjee et al., 2024). The combined application of manures, CR and BF increased SOC by 26%–53% (Meena, 2020). Specific organic inputs, such as pressmud, resulted in SOC levels of 7.39 g kg^{-1} (Bhosale et al., 2015), while the integration of microbial consortia with FYM yielded SOC levels of 14.7 Mg C ha^{-1} (Paul et al., 2016). Extended usage of FYM with inorganic fertilisers achieved a substantial 54.1% increase in SOC compared to controls (Biswas et al., 2023). Similarly, the combined usage of 50% organic inputs with natural inputs produced the highest oxidisable SOC values (1.12%), outperforming treatments relying on inorganic inputs (Sarkar et al., 2024). Soil moisture retention practices, such as the use of maize stover mulches, were also effective, leading to SOC levels of 13.4 g kg^{-1} (Singh et al., 2021). Diversified cropping systems, such as the maize–black gram–buckwheat rotation, contributed to sustained SOC enhancements (Babu et al., 2023). Despite some inconsistencies in statistically significant differences (Schweizer et al., 2022), the trend favours organic approaches for sustaining and enhancing SOC.

Physical soil health

Moisture content

Organic farming practices positively influence soil moisture content. Organic farms exhibited substantially higher soil moisture levels than their inorganic counterparts, recording 4.72% and 2.56% at different soil depths (Sahu et al., 2024). Conversely, the use of soil amendments, including pressmud (5%) and humus (5%), improved water retention capacity, achieving a value of 43 ± 0.014% (Bhosale et al., 2015).

Water holding capacity

The soil's water holding capacity (WHC) improves substantially with the application of organic inputs. In a rice-wheat-mungbean cropping sequence, the maximum WHC (56.3%) was achieved with a combination of VC and CR, while in the rice-wheat sequence, the highest WHC (56.0%) was observed with a treatment that incorporated VC, CR and BF (Meena et al., 2020). (Kaje et al., 2018) revealed that treatments utilising FYM consistently enhanced water retention across both depths (0–15 cm and 15–30 cm). Similarly, (Sarkar et al., 2024) recorded a WHC of 58.3% under fully organic treatments, with the highest WHC (58.52%) achieved through integrated nutrient management, which synergistically combined organic, natural and inorganic inputs.

Soil bulk density

Organic nutrient management practices have been shown to reduce soil bulk density (BD). A higher BD values (0.197 g/cc) at the 15–30 cm depth in organic farming systems compared to inorganic methods (Sahu et al., 2024). Applying FYM at 12 t ha^{-1} reduced soil BD from 1.37 Mg m^{-3} to 1.33 Mg m^{-3} (Babu et al., 2020). Similarly, (Meena et al., 2020) reported significant declines in BD values, with initial measurements of 1.50 Mg m^{-3} decreasing to 1.43–1.44 Mg m^{-3} under FYM + CR + BF treatments and 1.40–1.41 Mg m^{-3} under VC + CR + BF treatments following the twelfth cycle in rice-based cropping systems. (Kaje et al., 2018) found consistently lower BD across all soil depths under organic treatments compared to conventional systems. (Yadav et al., 2021) emphasised the impact of residue retention, reporting that applying 90% residue reduced BD by 0.05 Mg m^{-3}. (Singh et al., 2021) documented the highest BD values in no-mulching treatments, recording 1.34 Mg m^{-3} at a 0–15 cm depth and 1.36 Mg m^{-3} at 15–30 cm. However, (Sarkar et al., 2024) reported that BD remained unaffected by variations in nutrient treatments, while (Dubey et al., 2014) observed stability in BD over four cropping cycles within systems managed using 100% organic methods. (Babu et al., 2023) found the lowest BD in zero tillage systems (1.29 Mg m^{-3}) in comparison to decreased tillage (1.31 Mg m^{-3}) and traditional tillage (1.32 Mg m^{-3}) at a depth of 0–10 cm of soil.

Others

Organic farming practices significantly influence various physical soil properties. (Yadav et al., 2021) observed a 12% improvement in soil porosity over a five-year period, which was due to the retention of 90% crop residues. (Kaje et al., 2018) reported the highest soil porosity after 13 years of applying SGM+FYM+BGA for rice and LGLM+FYM+*Azotobacter* for wheat in sandy clay loam soils, across both layers (0–15 cm and 15–30 cm).

Regarding aggregate stability, (Schweizer et al., 2022) found that both BIODYN and BIOORG systems exhibited a 2.5 mg g^{-1} higher microaggregate stability compared to conventional farming methods. Additionally, organic systems showed a 4.2% increase in crack space, suggesting an improvement in soil structure. However, the rate of water infiltration was approximately 30% lower in BIODYN and BIOORG systems than in conventional systems with statistically significant differences ($p = 0.004$ for 3 hours; $p = 0.0001$ for 20 hours). These organic systems experienced 15% higher surface runoff, which emphasises the need for customised water management strategies to mitigate runoff losses.

(Babu et al., 2023) emphasised that tillage practices play a crucial role in influencing soil penetration resistance (SPR). Although no substantial differences were observed in the lower soil layers (11–15 cm), both zero tillage and reduced tillage practices were found to maintain lower SPR (1.32–1.46 MPa) in the 0–10 cm soil depth range in contrast to conventional tilling methods, which is vital for healthy root growth and soil conditions.

Discussion

This systematic literature review (SLR) highlights the significant improvements in soil health achieved through various organic farming practices in India, as measured by biological, chemical and physical properties. Organically managed farms demonstrated enhanced organic matter, enzymatic activity, microbial population, microbial biomass carbon, pH, electrical conductivity, nutrient levels, organic carbon, bulk density, water holding capacity and moisture content of soil. Organic inputs such as pressmud, FDP and humus have been linked to higher SOC because of their rich constituents of organic matter, nutrients, enzymes, proteins and microorganisms (Bhosale et al., 2015; Yadav & Garg, 2011). These inputs improve soil structure, thereby enhancing water and nutrient retention, aeration and water infiltration (Juwarkar & Jambhulkar, 2008). Additionally, the breakdown of organic substances supplies balanced carbon and nutrients, promoting microbial growth and soil health (Basak et al., 2012).

Soil moisture conservation practices have proven effective in enhancing quality of soil by increasing microbial populations beneath the surface and decreasing erosion (Ojeda et al., 2013; Yadav et al., 2021). Similarly, practices of retaining crop residue improve soil conditions by modifying hydrothermal properties to conserve moisture (Naresh et al., 2018). Retaining residue at higher level (90%) provides more biologically active carbon as a source of energy for microorganisms and stabilizes temperature and moisture, which creates a conducive environment for microbial proliferation (Li et al., 2020). Microbial activity also produces polysaccharides and organic acids, which enhance soil porosity and reduce bulk density (Agbede et al., 2008). Organic farming practices also positively influence enzymatic activities of soil by increasing microbial biomass and SOM (Yang et al., 2019). This impact can be attributed to elevated levels of macronutrients such as carbon, phosphorus and nitrogen derived from organic manures (Bhanuvally, 2024). Organic inputs act as catalysts, enhancing microbial activity, stabilizing extracellular enzymes by making complexes with humic substances and increasing microbial biomass carbon (Bhatt et al., 2016; Burns, 1982). Combined usage of organic and inorganic fertilizers further boosts soil enzymatic activity through greater microbial diversity (Mandal et al., 2007).

Organic inputs also influence soil pH. While green manure can acidify soil by generating organic acids (Goel et al., 2020; Manna et al., 2007), combined organic and inorganic fertilizer applications slightly lower soil pH due to acid production during organic matter decomposition (Bose et al., 2021). Hu et al. (2020) posited that such combined usage promotes organic matter degradation through microbial activity and produces organic acids. These organic acids, through increased cation exchange capacity and proton release, contribute to lowering of soil pH (Ross et al., 2008).

Furthermore, organic farming enhances soil nutrient levels. Urkurkar et al. (2010) showed that FYM reduces K fixation and improves K release by facilitating interactions between clay and organic matter. Enhanced nitrogen availability in organic farms, as noted by Meena et al. (2020), results from manuring, crop residue incorporation and biofertilizer use, which stimulate nitrogen mineralization via microbial activity. Additionally, nitrogen-fixing bacterial communities thrive in organic systems as the decomposition of organic compounds generates a nutrient flush, restoring soil nitrogen without synthetic fertilizers (Goel et al., 2020; Riggs & Hobbie, 2016). Overall, the present SLR proved the hypothesis that organic farming practices have a positive impact on soil health, contributing significantly to advancing environmental sustainability in India.

The present study acknowledges certain limitations. Firstly, this SLR concentrated on organic farming practice in India. As a result, the findings may not be as generalizable to other countries. Secondly, the current review sourced papers from specific databases including Science Direct, Springer Link and Google Scholar. However, important databases such as Scopus and Web of Science were not included in the study, which may have resulted in potentially overlooking relevant articles indexed in those databases. Finally, the study primarily focuses on soil health and environmental sustainability, potentially overlooking other critical dimensions such as economic and social sustainability of organic farming practices.

Conclusion and future directions

This systematic literature review highlights the diverse organic farming practices implemented across India, emphasizing their significant role in improving soil health and promoting environmental sustainability. The findings underscore the importance of integrating organic inputs such as farmyard manure, vermicompost, green-leaf manure and biofertilizers with innovative approaches like crop rotation, residue management and conservation agriculture. These practices not only enhance biological, physical and chemical characteristics of soil but also enhances the long-term viability of agricultural ecosystems.

While organic farming is practiced in India, its adoption remains limited across the country. In future, research should focus on developing region-specific organic farming models with the integration of advanced technologies for different agro-climatic zones in India. To meet the Sustainable Development Goals (SDGs) by 2030, it is imperative for farmers to rapidly adopt organic agriculture, which can simultaneously address global food demands and preserve environmental integrity. Strengthening farmer education and implementing supportive policies at both global and local levels will be essential for ensuring such widespread adoption and long-term success of organic farming practices in India.

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Annex

PRISMA 2020 Checklist

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	6
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	6
Study characteristics	17	Cite each included study and present its characteristics.	7
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	10
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	6-10
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	10
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	NA
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	NA
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	NA
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	NA
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	NA
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	10-11
	23b	Discuss any limitations of the evidence included in the review.	12
	23c	Discuss any limitations of the review processes used.	12
	23d	Discuss implications of the results for practice, policy, and future research.	11-12
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	NA
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	NA
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	NA
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	NA
Competing interests	26	Declare any competing interests of review authors.	NA
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	NA

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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