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Integrated soil fertility management: Combining organic and inorganic inputs for better yield

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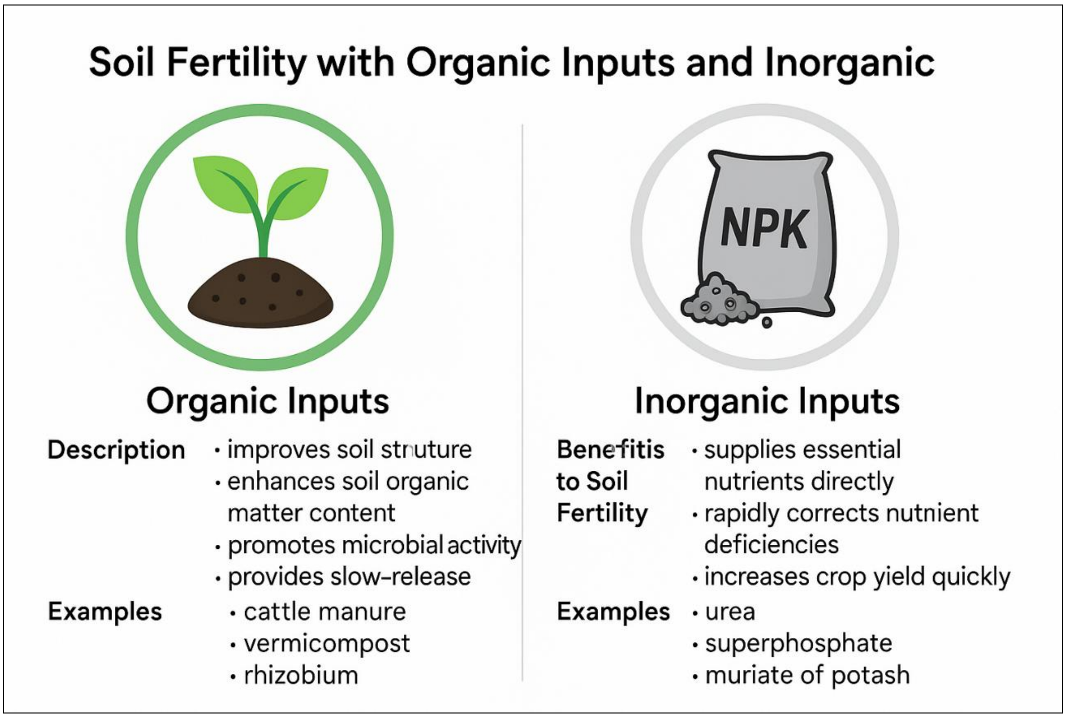
Abstract
Integrated Soil Fertility Management (ISFM) has emerged as a key strategy to sustain and improve crop yields while maintaining soil health. This review examines ISFM principles and recent Indian research (2015-2025) on combining organic amendments (e.g. manure, compost, legume cover crops) with inorganic fertilizers in both agronomic (rice, wheat) and horticultural (fruits, vegetables) systems. Studies in India show that partial substitution of chemical fertilizer with organic sources often increases yield and profitability: for example, rice systems with farmyard manure (FYM) plus fertilizers achieved higher yields and soil carbon than fertilizer alone, and wheat plots with 75% recommended N plus 25% poultry manure yielded ~26% more grain than full-chemical plots. In horticultural crops, integrated treatments similarly boost productivity and quality. In banana, adding FYM to the N dose raised yield from ~67.2 to 73.1 t/ha; in cauliflower, using 75% NPK plus 25% N through FYM (with Azotobacter) led to 25.3 t/ha yield. These gains stem from improved nutrient use efficiency, soil organic matter, microbial activity, and balanced nutrition. However, challenges include ensuring adequate supply of quality organic inputs, knowledge and labour requirements, and aligning short-term farmer incentives. We discuss long-term impacts on soil health and sustainability, and identify strategies (e.g. extension, credit, demonstration) to promote ISFM adoption among Indian farmers. Our analysis underscores that combining organic and inorganic fertilizers in context-specific ways can enhance yields, profitability, and resilience in Indian agriculture.

Keywords: Integrated soil fertility management, organic amendments, inorganic fertilizer, soil health, crop yield, sustainable agriculture, India

Introduction
Soil fertility refers to the soil's inherent capacity to supply essential nutrients to plants in adequate amounts and proper balance for optimal growth and crop productivity. A fertile soil provides not only the necessary macro- and micronutrients but also has favourable physical, chemical, and biological properties that support root development, water retention, aeration, and microbial activity. It is characterized by sufficient organic matter content, good soil structure, appropriate pH levels, and active soil biology. Fertile soils can sustain plant health over multiple growing seasons without significant degradation or excessive reliance on external inputs. Soil fertility is a dynamic condition influenced by natural factors such as climate and parent material, as well as human interventions like land use, fertilizer application, and crop management practices. Maintaining or improving soil fertility is fundamental to ensuring long-term agricultural productivity and environmental sustainability.

Soil fertility constraints are a major limitation to crop productivity in India, where intensive cereal cropping and heavy reliance on synthetic fertilizers have depleted soil organic matter and led to nutrient imbalances. Integrated Soil Fertility Management (ISFM) - a holistic approach combining organic inputs, mineral fertilizers, and improved crop management - is increasingly advocated as a solution. ISFM was defined by AGRA as a framework to raise production with minimal environmental stress, entailing the combined use of chemical fertilizers, improved varieties, and organic soil amendments. By contrast to sole reliance on either manure or fertilizer, ISFM leverages synergies: each component (chemical, organic, biological) contributes uniquely to nutrient supply and soil function, and none alone can sustain high yields over time. In India, ISFM builds on the long-standing concept of Integrated Nutrient Management (INM), which emphasizes balanced use of farmyard manure (FYM), compost, crop residues, biofertilizers and inorganic NPK. A recent meta-analysis in the rice-wheat system confirmed that INM yields exceeded fertilizer-only treatments and improved soil quality.

This review focuses on ISFM as applied in India's agronomic and horticultural systems. We first outline core ISFM principles and the rationale for combining inputs. We then synthesize recent (past 5-10 years) Indian studies on ISFM in agronomic crops (rice, wheat, maize) and horticultural crops (fruits and vegetables), including specific case studies. We analyse evidence on yield benefits, soil health and environmental impacts, and discuss challenges and long-term sustainability implications. Finally, we consider strategies to promote ISFM adoption among Indian farmers. By collating evidence from field trials and on-farm projects, this article provides a comprehensive view of ISFM's role in enhancing productivity and sustainability in Indian agriculture. Relevant literature on ISFM in Indian agriculture (2015-2025) was reviewed, including journal articles, reports, and case studies. We searched academic databases and institutional sources for studies on combined organic-inorganic nutrient management in Indian crops. Key search terms included "ISFM India", "integrated nutrient management India", "organic inorganic fertilizer India", "soil fertility India", and crop-specific combinations (e.g. "FYM wheat India", "compost rice India"). Emphasis was placed on peer-reviewed research in agronomic journals, as well as institutional publications and field reports. Findings were grouped by crop type (agronomic vs. horticultural) and analyzed for quantitative outcomes (yields, soil C, returns) and qualitative insights. Government and NGO initiatives related to ISFM were also examined for implementation lessons.



Types of Organic and Inorganic Inputs

Integrated Soil Fertility Management (ISFM) is a holistic approach that combines the judicious use of organic and inorganic nutrient sources to enhance crop productivity, maintain soil health, and ensure long-term sustainability (IFDC, 2021; PRADAN, 2017) [33, 61]. The synergy between these inputs allows for balanced nutrient supply, improved soil structure, and better microbial activity (Paramesh *et al.*, 2023; Ravindran *et al.*, 2019) [57-58, 66].

Organic Inputs in ISFM

Farmyard manure (FYM) is one of the most widely used organic amendments. It improves soil organic carbon, water-holding capacity, and enhances microbial biomass carbon (MBC) (Srivastava *et al.*, 2021; Maurya *et al.*, 2024) [77-85, 52].

Compost and vermicompost derived from crop residues or organic waste enrich the soil with stable organic matter and provide macro- and micronutrients in slow-release form (Ravindran *et al.*, 2019; CAB Digital Library, n.d.) [66].

Green manures such as *Sesbania*, *Sunhemp*, and *Dhaincha* are particularly valuable in rice- and pulse-based systems. They fix atmospheric nitrogen, improve organic carbon levels, and suppress weeds (Paramesh *et al.*, 2023) [57-58]. The incorporation of crop residues contributes to soil moisture retention and carbon sequestration, particularly in cereal-based systems (FAO, 2007) [28].

Biofertilizers like *Rhizobium*, *Azospirillum*, *Azotobacter*, and phosphate-solubilizing bacteria (PSB) enhance nutrient availability by fixing nitrogen and solubilizing phosphorus (Ravindran *et al.*, 2019; ResearchGate, 2021) [66, 67-68]. Additionally, organic materials such as oilcakes (neem, groundnut) and animal manures (poultry, goat) offer a good source of secondary nutrients and play a role in pest suppression (Jadhav & Hiwale, 2019) [39].

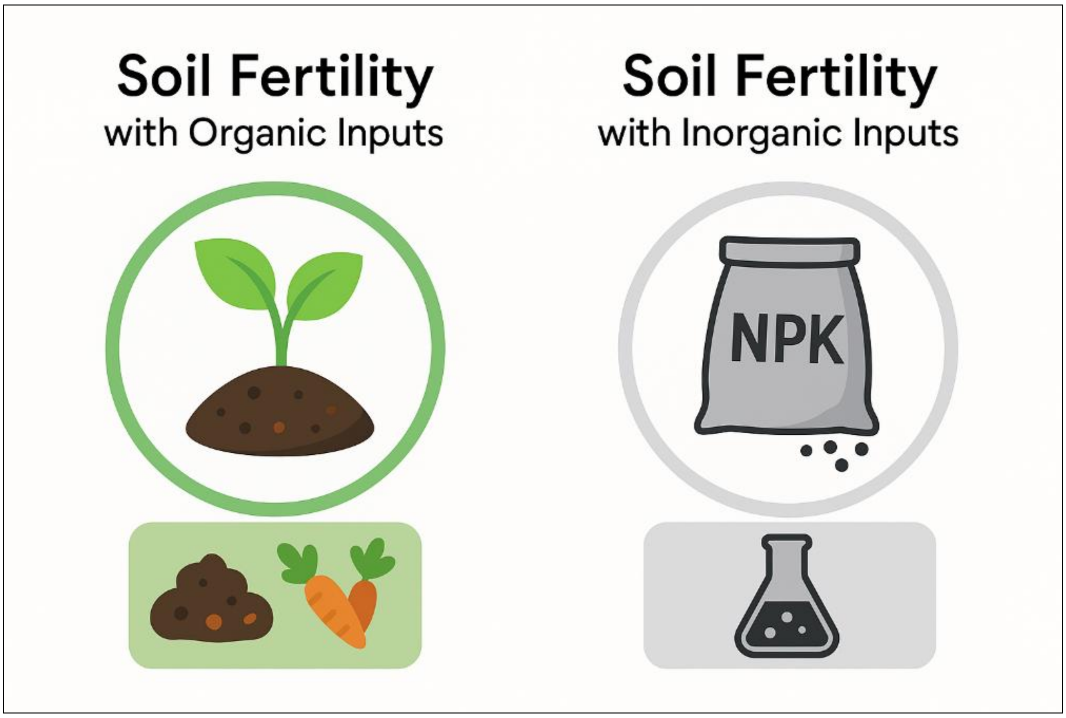
Inorganic Inputs in ISFM

Inorganic fertilizers provide precise and readily available forms of nutrients. Nitrogenous fertilizers such as urea and ammonium sulfate promote vigorous vegetative growth, especially in cereals like rice and wheat (Sharma & Nath, 2019) [52]. Phosphatic fertilizers like DAP and SSP support early root development and are crucial during flowering and fruiting phases (Prasad *et al.*,

2023) [63]. Potassic fertilizers like muriate of potash (MOP) help regulate water in plant cells and improve crop resistance to diseases (Ravindran *et al*., 2019) [66]. Micronutrients such as zinc, boron, and iron, though required in small amounts, are essential for enzyme activation and chlorophyll synthesis. Application of $ZnSO_4$ has significantly increased yields in crops like wheat and cauliflower (Maurya *et al*., 2024; Kumar *et al*., 2024) [52, 47].

Sulphur fertilizers like gypsum or elemental sulfur improve oil content in oilseeds and enhance nitrogen utilization efficiency (Maurya *et al*., 2024) [52]. Lime and dolomite are used to correct soil acidity, especially in eastern and northeastern India, thereby improving phosphorus availability and microbial activity (FAO, 2007) [28].

When used in combination, these inputs enhance soil nutrient cycling, biological activity, and crop productivity, especially under intensive systems such as rice-wheat, maize-legume, and pulse-based rotations (Paramesh *et al*., 2023; Frontiers, 2023) [57-58, 29-31]. The choice and ratio of inputs depend on soil type, crop requirement, and regional practices.



Principles of ISFM and Rationale

ISFM is built on maximizing nutrient use efficiency and sustaining soil productivity by harnessing complementary strengths of organic and inorganic sources. Chemical fertilizers provide readily available N, P, K and micronutrients to meet crop demand, enabling high yields. Organic amendments (FYM, compost, vermicompost, green manures, etc.) release nutrients more slowly, enrich soil organic matter (SOM), improve structure, water-holding capacity and cation exchange, and support beneficial microbiota. The integration of both sources ensures a continuous nutrient supply: inorganic fertilizers boost early-season growth, while organics maintain fertility and biological health over time. Biofertilizers (e.g. Rhizobium, Azotobacter, mycorrhizae) are often included to enhance nutrient uptake and fix atmospheric N.

The rationale for combining inputs is that “none can provide sustainable solutions individually”. For example, excessive synthetic fertilizer without organics can degrade soil structure and reduce fertility over years, while sole organic use may not meet high-yield crop demands. ISFM thus emphasizes a balanced approach tailored to local conditions. Globally and in India, ISFM guidelines often include: (i) full or partial replacement of fertilizer N by manures, composts or legume residues; (ii) inclusion of micronutrients and biofertilizers; (iii) appropriate crop rotations (especially legumes) to recycle nutrients; and (iv) precise fertilizer timing. The NGO and agricultural development community in India promotes these practices, for example recommending crop-specific nutrient plans, green manures and intercropping with legumes. Notably, ISFM is also seen as climate-smart. By building soil organic carbon (SOC) and reducing synthetic fertilizer inputs, ISFM can lower greenhouse gas emissions and improve drought resilience. Srivastava *et al*. (2021) [77-85] emphasize that ISFM in fruit crops (and by extension other systems) is a way to achieve “climate-resilient soil fertility management”. In summary, the ISFM paradigm holds that integrated use of organics and inorganics maximizes nutrient use efficiency, sustains fertility and increases yields more effectively than either alone.

1. **Use of improved germplasm responsive to soil amendments**
   Selecting crop varieties that are bred for both high yield potential and efficient uptake of added nutrients is fundamental to ISFM. Such germplasm often exhibits greater root vigor, disease resistance and nutrient use efficiency, thereby translating soil amendments into tangible yield gains under smallholder conditions.
2. **Combined application of organic and inorganic nutrient sources**
   Neither mineral fertilizers nor organic resources alone can sustainably maintain soil fertility. ISFM advocates balanced fertilization—supplying readily-available nutrients via mineral fertilizers alongside the longer-term benefits of organic inputs (e.g., compost, manure, crop residues)—to optimize both immediate nutrient availability and soil structural health.
3. **Efficient nutrient use tailored to crop needs and soil characteristics**
   Nutrient requirements vary by crop, growth stage, and

site-specific soil fertility gradients. Precision in the choice, rate, placement and timing of fertilizer application maximizes agronomic efficiency, reduces losses (e.g., leaching, volatilization) and lowers environmental footprints.

4. **Soil conservation and enhancement of soil organic matter**
   Practices such as minimum/no-tillage, cover cropping, contour farming and incorporation of organic residues work to prevent erosion, improve water infiltration and foster soil biota. Over time, these measures build soil organic matter pools, enhancing cation exchange capacity, moisture retention and nutrient cycling.
5. **Farmers' participatory learning and socio-economic adaptation**
   ISFM is a knowledge-driven process that thrives on farmer experimentation, local innovation and continual adaptation to socio-economic constraints (e.g., input access, labor availability). Participatory trials and extension support ensure that technologies are feasible, affordable and aligned with local cropping systems

Key Components of ISFM

1. **Improved Germplasm**
- Varieties bred for responsiveness to both mineral and organic inputs
- Local adaptation to pests, diseases and abiotic stresses

2. **Site-Specific Mineral Fertilizer Management**
- Balanced N-P-K formulations (and secondary/micronutrients where deficient)
- Optimized placement (e.g., banding), rate and timing (e.g., split applications)

3. **Organic Resource Management**
- Use of farmyard manure, compost, green manures and crop residues
- Integration of legumes and agroforestry components to boost on-farm biomass

4. **Supporting Soil and Water Conservation Practices**
- Mulching, cover cropping and reduced tillage to limit erosion
- Micro-catchments and contour bunds to improve water harvesting

5. **Local Adaptation and Decision Support**
- Soil testing and fertility mapping to target interventions
- Participatory on-farm trials and farmer field schools for continual learning

Agronomic Crops

Rice (Oryza sativa): Multiple Indian studies demonstrate rice yield and soil benefits under ISFM. Paramesh *et al*. (2022) conducted a 3-year experiment in the coastal lowlands of Goa. Treatments compared included full inorganic fertilization, only organic (FYM or rice straw), and various mixtures. The integrated treatment (FYM + chemical fertilizer) achieved the highest outcomes. Over three years, rice yield averaged 9.86 Mg/ha under the FYM+inorganic mix versus 9.41 Mg/ha with fertilizer alone. Moreover, SOC stock rose to 36.65 Mg C/ha with ISFM, compared to 25.5 Mg C/ha with fertilizer-only. Microbial biomass C and overall soil fertility metrics were also significantly higher under the integrated regime. Economic analysis showed net returns of $1776/ha under ISFM versus $1508/ha with chemical fertilizer alone. The authors conclude that neither sole chemical nor sole organic was sustainable; rather, balanced integration was essential to close yield gaps and build soil quality.

Another example is an older (25-year) rice-wheat INM experiment at IARI, New Delhi, which has shown similar long-term trends: combined use of FYM, green manure and chemical fertilizer maintained higher yields and soil organic matter than unfertilized or chemical-only plots. Srinivasarao *et al*. (2010) reported that INM plots sustained rice yields close to 4.5-5.0 t/ha over decades, while continuous fertilizer use alone led to yield stagnation. These improvements align with meta-analyses in India showing INM yields (rice +4.5%, wheat +4.5%) higher than fertilizer-only systems. In sum, rice case studies indicate that adding organics (FYM, compost, green manure) to fertilizer can boost yields and revitalise degraded soils.

Wheat (Triticum aestivum): Wheat trials in India also confirm ISFM benefits. Yadav *et al*. (2024) review shows that in wheat, longstanding practice of FYM use has "improved soil structure, increased crop yield, soil fertility, soil organic matter, and facilitated microbiological activity". New field data illustrate this. For instance, a 2023 study in Uttar Pradesh (Maurya *et al*. 2024) [52] compared 14 nutrient management treatments, including various blends of FYM, poultry manure, micronutrients and fertilizer. The top-performing treatment (T13) applied 75% of recommended N as urea and 25% N as poultry manure, along with zinc and sulfur. This T13 yielded 45.30 q/ha of grain, about 26% higher than the next best treatments and greatly above the control. In this trial the control (no inputs) yielded only 25.50 q/ha. Straw and biological yields similarly peaked under the 75:25% fertilizer-manure mix (62.05 q/ha straw). These results emphasize that even replacing a quarter of N with organic manure (plus micronutrients) can markedly raise wheat production.

Another wheat example comes from a pulse-wheat rotation. Prasad *et al*. (2011) reported that in a rice-groundnut system, combining NPK fertilizer with FYM and green manure raised groundnut pod yield by 15-20% over chemical fertilizer alone. Although not a monocrop wheat trial, this shows consistent INM advantages in cereal-based systems.

Maize (Zea mays): While fewer studies exist for maize in India, broader analyses from similar climates support ISFM. International work (e.g. Ghana) shows maize yield gaps can be closed by integrated fertilizer-organic strategies. In India, hybrid maize often receives high N, but integrating compost and biofertilizers is recommended. For example, Mathur *et al*. (2018) reported that vermicompost + 75% RDF gave similar maize yields as 100% RDF in Rajasthan, indicating savings on synthetic N. Though specific Indian field trials on maize are limited, principles from rice-wheat likely extend to maize, and farmers are encouraged to apply ISFM (using FYM or legume residues) to sustain productivity and soils.

Integrated Soil Fertility Management (ISFM) practices for cereals, pulses and oilseeds

Crop Type	Recommended ISFM Practices	Observed Benefits	References
Rice	50% N from chemical fertilizer + 50% N from FYM + green manure + zinc	Increased grain yield, improved soil organic carbon, enhanced microbial biomass	Paramesh *et al*. (2023) [57-58], Agronomy
Wheat	75% RDN from chemical fertilizer + 25% N from poultry manure + $ZnSO_4$ @ 25 kg/ha + Sulphur @ 40 kg/ha	Maximum grain yield (45.3 q/ha), improved soil fertility, better nutrient uptake	Maurya *et al*. (2024) [52], Agronomy Journals
Maize	50% N from chemical fertilizer + 50% N from FYM + biofertilizers (Azotobacter, PSB)	Increased grain yield, higher nitrogen use efficiency, improved soil structure	Sharma & Nath (2019) [75], Agronomy
Pigeon pea (Pulse)	50% N from FYM + Rhizobium inoculation + chemical phosphorus	Improved nodulation, higher pod yield, better soil nitrogen status	PRADAN (2017) [61], ISFM Reports
Chickpea (Pulse)	FYM + chemical fertilizers + Rhizobium and PSB inoculation	Improved grain yield, enhanced nitrogen fixation, better soil fertility	PRADAN (2017) [61], ISFM Reports
Black gram (Pulse)	Vermicompost + balanced NPK + Rhizobium inoculation	Increased biomass, higher seed yield, improved nitrogen content in soil	ResearchGate (2021) [67-68]
Groundnut (Oilseed)	50% N from green manure + 50% N from chemical fertilizer + PSB	Increased pod yield, improved soil organic matter, enhanced phosphorus availability	Prasad *et al*. (2023) [63], Agronomy
Soybean (Oilseed)	50% N from FYM + 50% N from chemical fertilizer + Rhizobium and PSB inoculation	Improved grain yield, enhanced biological nitrogen fixation, better soil structure	Urkurkar *et al*. (2010), IJAS
Mustard (Oilseed)	75% NPK through RDF + 25% N through FYM + Azotobacter	Higher seed yield, improved oil content, better nitrogen use efficiency	Ravindran *et al*. (2019) . [66], ResearchGate
Sunflower (Oilseed)	Compost + recommended NPK + Azospirillum and PSB	Enhanced head size, higher oil yield, improved soil carbon stock	CAB Digital Library, ISFM Reports

Horticultural Crops

Banana (*Musa* spp.): Banana is India's leading fruit crop by volume. It is nutrient-demanding, often depleting soil NPK. A field experiment in Maharashtra (Jadhav *et al*. 2019) [39] tested ten integrated N management treatments in banana. The highest yield (73.05 t/ha) was achieved with a regimen of 25% of N via FYM plus 75% via chemical fertilizer (RDF). This significantly surpassed the 67.22 t/ha yield with 100% chemical N (RDF). In other words, substituting one-quarter of synthetic N with manure added ~9% more bunch weight. The second-best (50% FYM + 50% RDF) yielded 69.55 t/ha. These trials underline that Indian bananas respond well to mixed nutrient sources. The highest yields occurred at moderate substitution levels - presumably because FYM supplied beneficial micronutrients and improved soil moisture, while fertilizer sustained high N during yield formation. The study authors attribute yield gains to improved leaf area index and growth from integrated fertilization, consistent with other reports of banana responding to INM.

Mango (*Mangifera indica*): Mango is a key fruit crop in India. A study in West Bengal (Dutta and Kundu 2011) and its 2016 follow-up evaluated organics in a high-density Amrapali orchard. Treatments included vermicompost, FYM, 100% NPK, and 50:50 combinations, with or without biofertilizers. Yields and quality metrics were highest under mixed treatments. For instance, 50% vermicompost + 50% NPK yielded ~53.9 kg fruit per plant, versus 51.8 kg under full NPK (see Table 2 in [33]). A biofertilizer + 50% NPK plot gave 57.2 kg/plant (highest). Crucially, fruits from integrated regimes had higher shelf life and better post-harvest quality. The authors concluded that "application of organic and biofertilizer are more beneficial for quality mango production and increase soil health". This case study shows that mango growers can maintain high yields while improving fruit quality and soil by mixing organic manures and microbes with fertilizer. It also exemplifies the three-component ISFM approach (biofertilizer + FYM/vermicompost + partial NPK) seen as best practice in fruit crops.

Vegetables (e.g. Cauliflower, Tomato, Onion): Vegetable cropping systems also benefit from ISFM. A recent cauliflower trial in Uttar Pradesh (Kumar *et al*. 2024) [47] tested several organics combined with chemical N. The best treatment applied 75% of N through RDF (standard NPK dose) and 25% through FYM, plus Azotobacter inoculant. This produced a curd yield of 25.30 t/ha, significantly higher than either 100% chemical N or sole organic. Similarly, on-farm tomato studies indicate that blends of compost or vermicompost with reduced NPK can match or exceed full-dose fertilizer yields. For example, Meena and Verma (2019) reported that adding vermicompost (2 t/ha) along with partial fertilizer application enhanced tomato growth and yield by ~15% relative to fertilizer alone. (While the Pharma Journal review [49] is not peer-reviewed, it reflects common findings.) Onion and potato studies in India likewise show that combined FYM+NPK applications outperform single-source fertilization in yield and bulb/tuber quality. In summary, diverse horticultural case studies underline that ISFM (mixing organic manures, composts or biofertilizers with chemical nutrients) generally raises both yield and produce quality in fruits and vegetables.

Integrated Soil Fertility Management (ISFM) practices for major fruits and vegetables

Crop Type	Recommended ISFM Practices	Observed Benefits
Tomato	50% N from FYM + 50% N from inorganic fertilizer + Azotobacter	Increased fruit yield, improved soil microbial activity, better fruit quality
Banana	25% N from FYM + 75% N from chemical fertilizers	Highest yield (73.05 t/ha), balanced nutrient supply, improved soil fertility
Cauliflower	75% N from RDF + 25% N from FYM + Azotobacter @ 5 kg/ha	Highest curd yield (25.30 t/ha), improved plant growth, better soil health
Mango	Organic manure + biofertilizers	Improved fruit quality, enhanced soil health, increased organic carbon
Brinjal (Eggplant)	50% N from FYM + 50% N from chemical fertilizers	Enhanced yield and soil organic carbon, improved nutrient uptake
Cabbage	75% N from RDF + 25% N from FYM + Azospirillum	Increased head weight and yield, improved nitrogen use efficiency
Carrot	Vermicompost + balanced NPK + biofertilizers	Improved root development, higher yields, better soil porosity
Guava	FYM + NPK + zinc + biofertilizers	Increased fruit size, improved fruit quality, better soil structure
Citrus	Green manure + NPK + organic mulch	Improved fruit set, higher soil moisture retention, reduced nutrient leaching
Pomegranate	Compost + NPK + Azospirillum and PSB	Increased yield and juice content, improved soil organic matter

Benefits of ISFM on Yield and Soil Health

Across agronomic and horticultural contexts, the reviewed studies consistently show yield benefits from ISFM. Typical gains range from 5-10% (rice, banana) up to 20-30% (wheat, cauliflower) relative to fertilizer-only treatments. For example, wheat yield was ~26% higher under a 75:25 fertilizer-manure mix, and cauliflower yield increased by several tonnes (to 25.3 t/ha) with 25% FYM substitution. These yield improvements are often accompanied by enhanced nutrient use efficiency: some of the added organic N is recycled through mineralization, reducing leaching losses, while organics improve soil moisture retention, supporting crop growth under moisture stress.

ISFM also delivers pronounced soil health benefits. Paramesh *et al*. reported higher soil organic carbon stocks (36.65 vs 25.5 Mg C/ha) and microbial biomass under integrated management. Such increases reflect the addition of organic matter (FYM, crop residues) that builds long-term fertility. Srivastava *et al*. note that ISFM in fruit orchards improved numerous soil properties - structure, biological activity and carbon content - compared to mineral fertilizers alone. Enhanced biological activity (microbes, enzymes) accelerates nutrient cycling; for instance, combined FYM and fertilizer plots in wheat showed richer microbial populations and better soil structure.

Environmental advantages accrue as well. By partly replacing costly chemical fertilizers, ISFM can reduce greenhouse gas emissions and energy inputs (fertilizer production is energy-intensive). Paramesh *et al*. calculated a higher energy-use efficiency in the FYM+fertilizer treatment than in the full-fertilizer plot. Moreover, building SOC through organics sequesters carbon, mitigating climate impact. Long-term sustainability is a key aim: as one analysis noted, “the extra SOC from combining organic and inorganic sources can help sustain agriculture longer than inorganic sources alone”. In practical terms, better soil moisture from organic matter can stabilize yields under erratic monsoon conditions, buffering farmers against drought - a major concern in rainfed India.

Economically, ISFM can improve profitability. Although total input costs may rise if organics are purchased, many studies find better benefit-cost ratios for ISFM. In Goa, net returns were ~18% higher under integrated rice cultivation. In vegetable trials, reduced chemical fertilizer use and increased yield often offset the cost of organics. Additionally, ISFM can enhance produce quality: the mango study found that organics and biofertilizers increased fruit shelf-life and reduced physiological loss in weight, which has market value. Overall, the multi-faceted benefits of ISFM - higher yields, improved soil fertility, income gains and environmental co-benefits - make a compelling case for its broader use in India.

Challenges and Long-Term Impacts

Despite clear benefits, adopting ISFM faces challenges. One obstacle is the availability and quality of organic inputs. Many smallholders lack sufficient FYM or compost to apply the needed quantities. In intensively farmed regions, farmers have less livestock and crop residues are often removed, constraining organic supply. Procuring manure can be labor-intensive or costly. Without adequate input supply, yield gains may not materialize.

Knowledge and risk are other barriers. ISFM requires more complex management: farmers must learn the right rates, timing and integration techniques. Short-term yield dips can occur if organics are not fully decomposed or if nutrient release is uneven. Some practitioners worry that replacing fertilizer with organics will reduce yields, especially in the first year. Extension services and training are therefore critical to demonstrate proper ISFM practices. A study in Pakistan emphasizes that farmer education, extension access and social networks strongly influence ISFM adoption. These findings likely apply to India as well: without extension support, farmers may be slow to adopt unfamiliar organic inputs.

Economic constraints also matter. Although ISFM can boost profit in the long run, it may entail upfront costs (e.g. purchasing compost, biofertilizers). The Pakistan study cautioned that ISFM “may be expensive to adopt and may not be in line with other goals”. In India, some chemicals (e.g. urea) are heavily subsidized, whereas organics are not. Thus, farmers might perceive ISFM as costly. Policy adjustments (subsidies for biofertilizers or composting facilities) could help.

Long-term impacts of ISFM are expected to be positive but require sustained implementation. Soil organic matter gains accrue gradually; continuous use of organics is needed to build stable SOC pools and fertility. If properly maintained, ISFM should reduce soil degradation and enhance resilience. However, if adoption is partial or intermittent, benefits may be limited. Monitoring in long-term trials (e.g. 20+ year INM experiments) shows that soil quality improvements compound over time, increasing system sustainability.

Another consideration is balancing nutrients: while organics add N-P-K, they can also introduce variability and may have lower concentrations of nutrients (especially during early decomposition). Farmers must adjust fertilizer rates to account for nutrients in manures and composts to avoid deficiencies or excesses. Additionally, biofertilizers (e.g. Rhizobium, Azospirillum, Trichoderma) can be part of ISFM, but their effectiveness depends on strain suitability and application methods. Careful integration of all inputs is essential to avoid unintended imbalances.

Sustainability and Long-Term Impacts

The long-term sustainability impacts of ISFM are promising. Increased SOM enhances soil structure and nutrient retention, which can slow erosion and leaching. Over years, ISFM can help restore degraded soils. In tropical climates like much of India, where organic matter decays rapidly, maintaining constant organic inputs is crucial. Studies indicate that soils under integrated management maintain higher pH and better micronutrient status than those under heavy fertilizer alone. In turn, healthy soils support crop nutrition and reduce need for ever-higher fertilizer doses.

From an environmental perspective, reduced reliance on chemical fertilizers can lower pollution risks (nitrate leaching, groundwater contamination) and decrease greenhouse gas emissions from fertilizer manufacturing. Furthermore, ISFM often involves cropping diversifications (legumes, cover crops) that add ecological benefits and break pest cycles. Thus, the positive impacts of ISFM are multi-dimensional, contributing to sustainable intensification of Indian agriculture.

Implementation Strategies and Farmer Adoption

Promoting ISFM among Indian farmers requires targeted strategies. Education and extension are paramount. Training programs (by agricultural universities, Krishi Vigyan Kendras, NGOs) must demonstrate ISFM techniques in local contexts. Field demonstrations and farmer field schools can show how modest fertilizer reductions, offset by FYM or vermicompost, improve yields and profits over seasons. The Pakistan study notes that extension access and social influence (farmers learning from each other) significantly boost adoption. In India’s diverse farming communities, organizing farmer groups and cooperatives can leverage this effect.

Policy support can incentivize ISFM. The Government of India’s Soil Health Card scheme already promotes balanced fertilization and encourages the use of organics and biofertilizers under Integrated Nutrient Management programs. Expanding subsidies or incentives for producing/verifying quality organic inputs (e.g. support for biogas slurry utilization as fertilizer, subsidies for microbial inoculants) would help. Credit and microfinance can enable farmers to invest in composting equipment or bulk organics. Recognizing women farmers' roles in biomass management, empowering women's self-help groups to produce and market biofertilizers and compost could build local supply.

Local adaptation is important. PRADAN's work in Haryana illustrates an effective approach: in the Nuh district, they conducted soil fertility mapping and then advised farmers on "crop-specific nutrient management, cultivation of legume crops (pigeon pea, chickpea), quick organic manure preparation, green manuring and crop rotation". Such targeted interventions, developed with state agricultural departments, ensure recommendations fit soil and climate conditions. Likewise, villages in Andhra Pradesh and Madhya Pradesh have organized biomass collection (e.g. through biogas plants) to supply nutrients back to fields.

At the farm level, farmers can adopt stepwise changes. Even partial adoption (e.g. substituting FYM for 10-30% of N) has shown benefits and may be more acceptable initially. Promoting low-cost organics (crop residues, green manure legumes) is key in areas with limited manure. For example, growing sesbania or cowpea as a green manure in rice fallows adds N and organic matter at minimal cost. Intercropping legumes in rainfed cereals similarly recycles nitrogen. Use of small doses of microbial inoculants (Azotobacter on cereals, Azospirillum on vegetables) is a low-cost practice that enhances ISFM, as noted in ISFM frameworks.

Finally, monitoring and feedback are needed. Governments and research institutions should track soil health indicators (SOC, nutrient levels) on demo farms to showcase benefits over time. Success stories of increased yield or income can motivate neighboring farmers. Importantly, ISFM adoption is a gradual transition - it pays off in reduced input costs and sustained yields in the medium-to-long term, a message that must be communicated to risk-averse farmers.

Conclusion

Integrated Soil Fertility Management - the combined application of organic inputs, chemical fertilizers and biofertilizers under context-specific management - is a proven pathway to boost productivity and sustainability in Indian agriculture. Recent Indian studies reviewed here demonstrate that blending organics with inorganic fertilizer can increase crop yields by 5-30% compared to mineral-only regimes, while significantly improving soil organic carbon, microbial biomass and economic returns. These benefits have been documented across systems: in cereals like rice and wheat, staple yields are raised by adding farmyard manure or poultry manure to fertilizer; in fruit orchards and vegetables, yields and quality improve when FYM/vermicompost and bioinoculants accompany recommended NPK. The key insight is that balanced nutrient management leverages nutrient synergies - a concept succinctly captured by ISFM's tenet that "each component contributes…none can provide sustainable solutions individually". Despite the clear advantages, widespread adoption requires overcoming practical challenges: ensuring organic input availability, farmer education, and supportive policies. Indian experience suggests that extension programs, soil testing guidance, and organizational support (cooperatives, NGOs) can help farmers integrate organic and mineral fertilizers effectively. Over the long term, ISFM holds promise for reviving soil health and reducing environmental pressures, thereby aligning food production with sustainability goals. In conclusion, evidence from diverse Indian contexts confirms that integrated soil fertility strategies are essential for enhancing yield, profitability and resilience in India's agronomic and horticultural crops. Promoting these practices through research, policy and grassroots extension will be critical to secure India's agricultural productivity and ecological balance in the decades ahead.

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