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Warehousing and Storage Challenges and Opportunities in Organic Supply Chains: A Systematic Literature Review with Special Reference to South Tamil Nadu

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Abstract: *Effective warehousing and storage infrastructure is central to the commercial viability of organic agri-food supply chains, particularly in smallholder-dominated production systems where post-harvest handling remains inadequate, cold storage access is limited, and inventory management capabilities are nascent. This systematic literature review examines warehousing and storage challenges and opportunities in organic supply chains, with particular emphasis on the South Tamil Nadu regional context. Following a PRISMA-informed protocol, 28 sources were retained for thematic synthesis from an initial pool of 60 identified records drawn from Scopus, Web of Science, Google Scholar, and relevant grey literature sources. The review identifies five dominant challenge domains: cold storage infrastructure deficits, post-harvest handling losses, organic product quality deterioration during storage, absence of farmer-level inventory management systems, and structural disconnection between storage capacity and market demand. Correspondingly, five opportunity domains emerge: Farmer Producer Organisation (FPO)-led shared warehousing, affordable pre-cooling and cold chain technology adoption, digital inventory management tools, warehouse receipt financing, and policy-supported aggregation centre development. The review proposes a four-pillar improvement framework — infrastructure, technology, policy and institutions, and capacity building — as a practical guide for supply chain interventions, and identifies critical gaps in region-specific empirical research.*

Key Words: *Organic supply chain, Warehousing, Cold storage, Post-harvest loss, South Tamil Nadu, Farmer Producer Organisation, Storage infrastructure.*

1. INTRODUCTION:

Warehousing and storage infrastructure constitutes a foundational element of any agri-food supply chain, yet it remains among the most underemphasised dimensions in the academic and policy discourse on organic agriculture. For perishable organic products, the adequacy of storage at each stage of the supply chain — from the farm gate through aggregation, wholesaling, and retail — determines not only whether sufficient quantities of produce reach consumers, but whether the quality premium embedded in organic certification is preserved until the point of sale. When storage conditions are suboptimal, both the physical product and the embedded economic value are simultaneously degraded.

Globally, post-harvest losses in fresh fruit and vegetable supply chains are estimated at 20–50 percent of harvested volume, with a significant proportion occurring during storage, handling, and transportation.[1] In low- and middle-income countries, where cold chain infrastructure is least developed relative to production volumes, these losses represent a disproportionate drain on smallholder farmer income.[1] India presents a particularly significant case: by 2022-23, India's certified organic cultivation area exceeded 3.9 million hectares, encompassing over 1.6 million certified farmers.[2] Yet the cold chain and warehousing infrastructure supporting this expanding organic sector — particularly at the farm gate and first-mile level — remains critically underdeveloped relative to production scale.[3]

South Tamil Nadu, encompassing the districts of Madurai, Tirunelveli, Virudhunagar, Thoothukudi, and Dindigul, represents a significant organic production zone with cold storage capacity in these five southern districts accounting for less than eight percent of the state's total installed cold storage capacity.[3] Smallholder organic farmers in this region

primarily operate under the Participatory Guarantee System (PGS-India), which certifies compliance with organic input standards but does not structurally address post-harvest storage or handling infrastructure. The result is a consistent and largely undocumented pattern of post-harvest losses that erode both farmer income and the reliability of the organic premium.

Despite the growing academic literature on organic certification and market access, warehousing and storage challenges specific to organic supply chains — and their interplay with quality, income, and market connectivity — have received comparatively limited systematic attention, particularly with regional specificity to South Tamil Nadu. This systematic literature review addresses that gap by examining the available literature on warehousing and storage challenges and opportunities in organic supply chains, drawing specific implications for the South Tamil Nadu context.

2. LITERATURE REVIEW:

2.1 Organic Supply Chains and Their Logistical Complexity

Organic agri-food supply chains differ from conventional supply chains in several logistically significant respects. The prohibition on synthetic preservatives and post-harvest chemical treatments means that the shelf life of unrefrigerated organic produce is materially shorter than that of its conventional equivalent.[4] Negi and Anand[4] identify certification verification, product segregation to prevent contamination with conventional produce, and premium realisation at the consumer end as the three most logistically demanding aspects of organic supply chain management in India. Their analysis suggests that storage inadequacy sits at the intersection of all three challenges: where cold storage is shared between organic and conventional produce without proper segregation, certification integrity is compromised; where produce is held under ambient conditions, quality deteriorates faster than in conventional supply chains; and where storage duration cannot be controlled, market timing opportunities are forfeited.

2.2 Warehousing and Storage in Agri-Food Supply Chains

Raut et al.[6] identify the lack of appropriate post-harvest facilities as a critical success factor that, when absent, propagates losses through subsequent stages of the supply chain, reducing both quantity and quality available for the market. Chandel et al.[7] document that cold chain infrastructure in India remains concentrated in a small number of commercially dominant states and districts, leaving horticultural and diversified organic production zones in South India significantly underserved. The structural consequence, as Murthy et al.[8] observe, is that smallholder farmers in horticulture-intensive regions bear the market and quality risks associated with inadequate storage infrastructure most acutely, because they lack the capital to invest in private cold room facilities and cannot access public cold storage on commercially competitive terms.

2.3 Post-Harvest Storage Issues and Organic Product Quality

Post-harvest losses in India's fresh produce sector are estimated between 25 and 40 percent across commodities, with horticultural produce experiencing the highest loss rates.[8] For organic produce specifically, the absence of post-harvest chemical treatments amplifies spoilage risk during storage.[9] Arah et al.[9] demonstrate that tomatoes and leafy vegetables stored under ambient conditions exceeding 25°C lose between 15 and 30 percent of marketable weight within 48–72 hours of harvest. Applied to South Tamil Nadu, where ambient temperatures during the primary harvest season of March to June routinely exceed 35°C and farm-to-storage transit may span six to eight hours, these loss rates are indicative rather than conservative.

2.4 Cold Chain Infrastructure and Temperature-Controlled Storage

Mangal et al.[10] document that the availability of first-mile cold storage reduces fresh produce post-harvest losses by between 20 and 40 percent in comparable Indian horticultural supply chains. The FAO[11] provides corroborating global evidence, estimating that cold chain improvements in developing countries can reduce food losses by 14–17 percent at national level. Singh and Dhaliwal[12] document that IoT-based temperature monitoring in refrigerated transport vehicles significantly improves cold-chain accountability and reduces quality disputes — a finding with direct application to organic supply chains where premium justification depends on demonstrable handling standards.

2.5 Inventory Management and Shelf-Life Challenges

Wognum et al.[13] argue that transparency systems enabling real-time inventory visibility are a prerequisite for managing organic supply chains effectively, as the absence of such systems makes it difficult to respond to demand fluctuations without incurring spoilage. Eriksson et al.[14] demonstrate in a retail cold storage context that structured cold storage and inventory management systems reduced food waste by between 8 and 15 percent for fresh organic produce.

Govindan[15] reinforces this point, identifying real-time inventory visibility and dynamic stock rotation as necessary conditions for aligning organic supply chain throughput with demand.

2.6 Storage Infrastructure for Smallholder Farmers and FPOs

Trebbin[16] documents that producer organisations in India that invest collectively in aggregation and storage infrastructure achieve significantly better price realisation for their members than those without such infrastructure. The SFAC[17] review confirms that FPOs engaged in primary processing and storage activities demonstrate stronger financial sustainability and member retention. Krishnamurthy and Balasubramanian[18] document that PGS-certified organic producers accessing direct marketing channels realise 25–40 percent higher farm-gate prices — but consistent quality, which requires adequate storage, is a prerequisite for accessing these channels.

2.7 South Tamil Nadu Organic Supply Chain Context

Padmanaban and Krishnan[19] identify infrastructure constraints as the primary structural barrier to supply chain formalisation in Tamil Nadu's organic sector, documenting that producers regularly absorb 30–40 percent price reductions because they cannot delay sale long enough to access premium-willing buyers. Arunachalam[20] notes that the price premium documented in consumer surveys is substantially not transmitted to producers due to post-harvest quality loss and intermediary capture. The NABARD assessment[3] provides authoritative quantification of the storage infrastructure gap, confirming that less than eight percent of Tamil Nadu's total cold storage capacity is located in the five southern districts.

3. OBJECTIVES :

1. To systematically review the published literature on warehousing and storage challenges in organic agri-food supply chains.

2. To identify the primary storage-related gaps affecting organic product quality, shelf life, and market access.

3. To analyse documented and emerging opportunities for improving warehousing and storage efficiency in organic supply chains.

4. To examine the relevance of warehousing and storage challenges in the South Tamil Nadu organic supply chain context, with specific reference to the five southern districts.

5. To propose evidence-based recommendations for organic farmers, FPOs, supply chain managers, warehousing service providers, and policymakers.

6. To identify gaps in the current literature and suggest directions for future empirical research.

4. RESEARCH METHOD / METHODOLOGY:

4.1 Systematic Literature Review Design

This study adopts a Systematic Literature Review (SLR) design, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[21] The SLR methodology was selected because it provides a transparent, reproducible, and audit-able framework for identifying, screening, and synthesising literature on a defined research question. Given the absence of prior systematic reviews specifically addressing warehousing and storage challenges in organic supply chains with a South Tamil Nadu focus, the SLR approach is particularly appropriate.

4.2 Database Selection and Search Strategy

Systematic searches were conducted across: Scopus; Web of Science (Core Collection); Google Scholar; EBSCO Business Source Complete; MDPI; Emerald Insight; Taylor & Francis Online; and Wiley Online Library. Grey literature was searched through FAO, NABARD, APEDA, SFAC, and TNAU institutional repositories. The search applied Boolean combinations across three keyword clusters: (a) subject terms — warehousing, cold storage, post-harvest storage, storage infrastructure, inventory management; (b) sector terms — organic supply chain, organic agriculture, organic food logistics, agri-food supply chain; and (c) geographical terms — India, Tamil Nadu, smallholder, farm-to-consumer, Farmer Producer Organisation. Table 2 presents the search strategy and database coverage.

Table 2: Search Strategy and Database Coverage

Database / Source	Search String Applied	Initial Records	Retained
Scopus	("warehousing" OR "cold storage" OR "post-harvest storage") AND ("organic supply chain" OR "organic agriculture") AND ("India" OR "smallholder")	16	8
Web of Science	Same string — WoS Core Collection (SSCI, ESCI)	12	6
Google Scholar	"organic supply chain" "cold storage" "post-harvest loss" "India" OR "Tamil Nadu"	11	4
EBSCO / MDPI / Emerald / Taylor & Francis / Wiley	"storage infrastructure" OR "inventory management" AND "organic food" AND "smallholder"	13	4
Grey Literature (FAO, NABARD, APEDA, SFAC, TNAU)	Manual keyword search: cold storage, organic supply chain, post-harvest, Tamil Nadu	8	6
Total		**60 (54 after deduplication)**	**28**

Source: *Authors' compilation. Coverage period: 2009–2024.*

4.3 Inclusion and Exclusion Criteria

Table 3 presents the inclusion and exclusion criteria applied during the screening process.

Table 3: Inclusion and Exclusion Criteria

Criterion	Inclusion	Exclusion
Language	English-language publications	Non-English publications without English abstracts
Publication period	2009–2024; foundational sources pre-2009 accepted	Publications pre-2009 unless foundational or frequently cited
Topic relevance	Warehousing, storage, cold chain, post-harvest handling, inventory management in organic or agri-food supply chains	Studies with no warehousing or storage focus; purely demand-side or certification studies
Sector focus	Organic agri-food supply chains; smallholder agriculture; farmer organisations	Large-scale industrial food processing with no smallholder relevance
Geography	India, South Asia, or comparably structured developing country contexts	High-income, industrialised country settings with no transferable insights
Source type	Peer-reviewed journals; institutional and government reports with identifiable methodology	Opinion pieces, editorials, promotional content, and sources without verifiable methodology

Source: *Authors' review protocol.*

4.4 PRISMA Screening Flow and Data Extraction

From 60 total records identified (52 from databases and 8 from grey literature), 6 duplicates were removed yielding 54 unique records. At title and abstract screening, 16 records were excluded, leaving 38 for full-text review. Following full-text assessment, 10 further records were excluded — 7 for absence of warehousing or storage focus, and 3 for non-organic or non-transferable contexts — yielding 28 sources retained for thematic synthesis. Figure 1 presents the PRISMA-style literature selection flow.

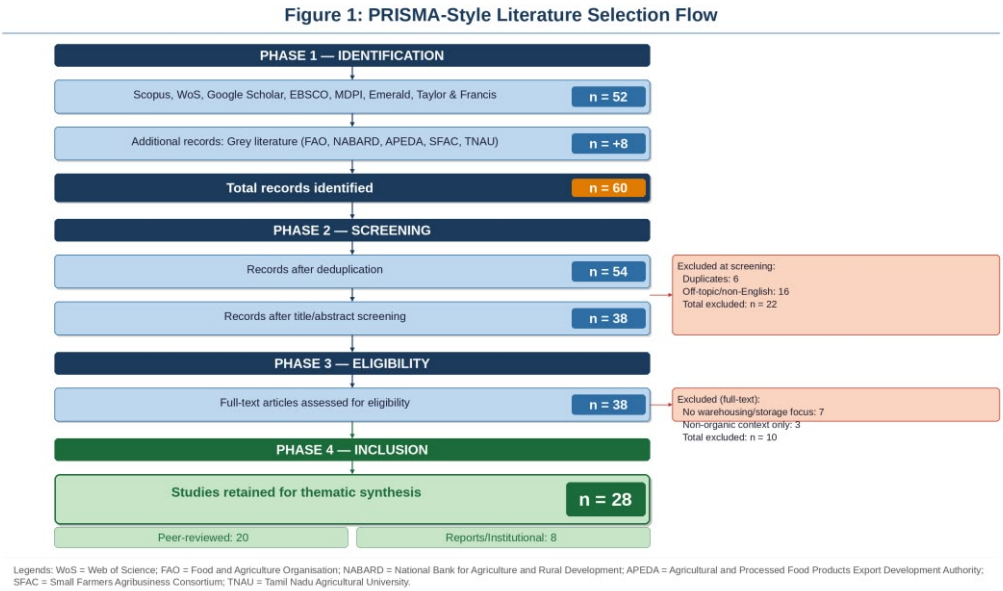

Figure 1: PRISMA-Style Literature Selection Flow

Legends: *WoS = Web of Science; FAO = Food and Agriculture Organisation; NABARD = National Bank for Agriculture and Rural Development; APEDA = Agricultural and Processed Food Products Export Development Authority; SFAC = Small Farmers Agribusiness Consortium; TNAU = Tamil Nadu Agricultural University.*

Table 1: Summary of Key Reviewed Literature

No.	Author(s) & Year	Method	Context	Key Contribution
1	FAO (2019)	Report	Global	Post-harvest losses 20-50% in fresh produce; cold chain as primary mitigation lever
2	NABARD (2021)	Institutional report	Tamil Nadu	Cold storage in five southern TN districts <8% of state total; geographic maldistribution documented
3	Negi & Anand (2016)	Case study	India	Certification integrity, product segregation, and premium realisation as key organic SCM challenges
4	Raut et al. (2018)	DEMATEL	India	Post-harvest facility absence as critical failure factor propagating losses through supply chain
5	Mangal et al. (2020)	Empirical	India	First-mile cold storage reduces fresh produce losses by 20-40%; most impactful single investment
6	Trebbin (2014)	Empirical	India	FPOs investing collectively in storage achieve significantly better price realisation for members
7	Krishnamurthy & Balasubramanian (2022)	Survey	Tamil Nadu	PGS-certified direct-market producers realise 25-40% higher farm-gate prices; quality requires storage
8	Padmanaban & Krishnan (2022)	Exploratory	Tamil Nadu	Storage absence forces distress sales; producers absorb 30-40% discount vs organic premium price
9	Singh & Dhaliwal (2023)	Empirical pilot	India	IoT temperature monitoring improves cold-chain accountability in agricultural supply chains
10	FAO (2014)	Report	Global	Cold chain improvements can reduce national food losses by 14-17%; highest gain in fresh produce

Source: *Authors' synthesis. Table presents 10 illustrative entries from 28 retained sources.*

5. FINDINGS :

Thematic synthesis of the 28 retained sources produced five recurring challenge domains and five corresponding opportunity domains. Figure 2 presents the organic supply chain storage flow from farm gate to consumer. Tables 4 and 5 present the challenges and opportunities in detail.

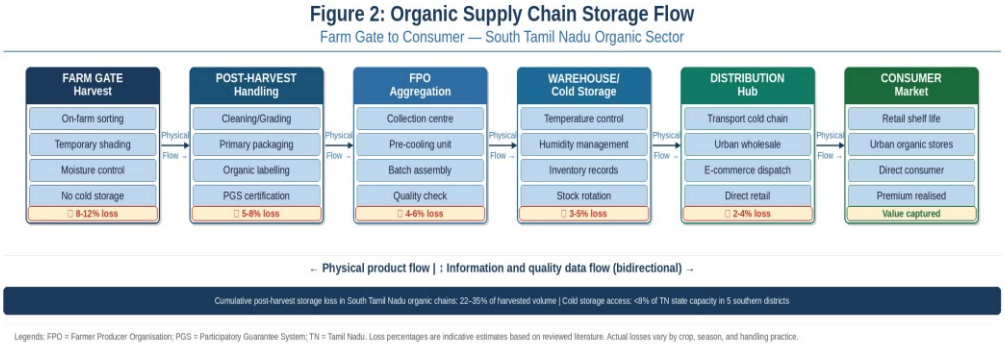

Figure 2: Organic Supply Chain Storage Flow — Farm Gate to Consumer (South Tamil Nadu)

Legends: *FPO = Farmer Producer Organisation; PGS = Participatory Guarantee System; TN = Tamil Nadu. Loss percentages are indicative estimates based on reviewed literature.*

Table 4: Major Warehousing and Storage Challenges in Organic Supply Chains

No.	Challenge Domain	Description and Evidence	South TN Relevance
C1	Cold Storage Infrastructure Deficit	Cold storage in TN's five southern districts is <8% of state total. First-mile cold storage is absent near most organic production clusters. Installed capacity primarily serves potato/onion, leaving organic horticulture chronically underserved.	Very High. Madurai, Tirunelveli, Virudhunagar, Thoothukudi, and Dindigul all face acute cold storage access gaps.

C2	Post-Harvest Handling Losses	Organic produce stored under 30-37°C during March-June harvest season loses 15-30% of marketable weight within 48-72 hours. Without approved chemical treatments, cold storage is the only quality preservation mechanism. Cumulative losses: 22-35% of harvested volume.	Very High. South TN's hot-season harvest conditions amplify ambient-temperature storage losses well beyond national averages.
C3	Organic Quality Deterioration	Absence of synthetic preservatives makes organic produce more perishable than conventional equivalents. Certification integrity is compromised when organic produce is co-stored with conventional produce in shared warehouses without segregation.	High. PGS-India certified produce in South TN has no structured warehouse management protocol ensuring organic segregation.
C4	Inventory Management Inadequacy	Most smallholder organic farmers and FPOs in South TN lack digital inventory tools, real-time stock visibility, or formal rotation and quality monitoring systems. Stock accumulation, delayed marketing, and distress sales result.	High. Very few FPOs in southern districts have implemented warehouse management software or digital stock records.
C5	Storage-Market Demand Disconnection	Even where limited storage is available, the absence of market linkage information means storage is not used to time sales at demand peaks. Organic produce is often sold at harvest regardless of market price levels.	High. Price volatility in Madurai and Tirunelveli organic markets is partly attributable to harvest-concentrated supply that storage could moderate.

Source: *Authors' synthesis. NABARD (2021)[3]; Padmanaban & Krishnan (2022)[19]; Mangal et al. (2020)[10]; Arah et al. (2016)[22].*

Table 5: Opportunities for Improving Warehousing and Storage in South Tamil Nadu Organic Supply Chains

No.	Opportunity Domain	Description and Evidence	Implementation Pathway in South TN
O1	FPO-Led Shared Warehousing	Collective investment in storage infrastructure through FPOs reduces per-unit storage cost. Trebbin (2014) and SFAC (2023) document that FPOs with storage assets achieve better price realisation and member retention.	FPOs in Madurai, Virudhunagar, and Tirunelveli can leverage NABARD's FPO promotion fund to establish shared pre-cooling units at collection centres.
O2	Affordable Pre-Cooling Technology	Evaporative cool chambers, zero-energy cool rooms, and low-cost pre-cooling units offer affordable alternatives to conventional refrigeration. FAO (2014) documents 3-7 day shelf life extension at fraction of conventional cold storage capital cost.	Pre-cooling units within 3-5 km of FPO collection centres in Madurai and Dindigul upland production areas would address first-mile gap at accessible cost.
O3	Digital Inventory Management	Mobile-based inventory management tools — stock entry apps, SMS-based lot tracking, low-cost warehouse management systems — are increasingly accessible in rural India. Aggarwal and Srivastava (2020) document successful adoption in comparable smallholder contexts.	TNAU and state agriculture department digital extension can facilitate basic inventory tracking tool adoption among FPOs in the southern districts.
O4	Warehouse Receipt Financing	Warehouse receipt systems (WRS) allow farmers to use stored produce as collateral for short-term credit, enabling holding produce without immediate cash flow pressure. WRS is documented for grain storage in India with extension potential to organic produce.	PGS-India's certification documentation provides a quality basis for organic produce warehouse receipts; pilot WRS programs through NABARD-linked institutions could be initiated.
O5	Policy-Supported Aggregation Centres	Publicly supported rural aggregation centres combining grading, primary processing, short-term storage, and market linkage are documented as high-impact investments. APEDA's export support and PM Kisan Sampada Yojana provide policy vehicles for financing.	Targeted aggregation centre development in Virudhunagar (organic cotton), Madurai (millet), and Tirunelveli (horticulture) would address storage deficit and market access simultaneously.

Source: *Authors' synthesis. Trebbin (2014)[16]; SFAC (2023)[17]; FAO (2014)[11]; Aggarwal & Srivastava (2020)[23]; APEDA (2023)[2].*

6. DISCUSSION :

6.1 Production-to-Storage Issues in South Tamil Nadu

The reviewed literature collectively suggests that post-harvest storage challenges in South Tamil Nadu's organic supply chains originate at the moment of harvest and propagate through each subsequent handling stage. The lack of on-farm cooling or covered storage means that freshly harvested organic produce — which, absent synthetic post-harvest treatments, begins deteriorating faster than its conventional equivalent — is exposed to ambient temperatures during the most critical quality-controlled window.[12] In the five southern districts, daytime temperatures during the March-to-June harvest season routinely exceed 35°C, and the absence of first-mile cold storage can render three to four hours of ambient exposure sufficient to initiate quality deterioration that makes produce unmarketable through premium organic channels.[10]

6.2 Storage-to-Market Flow and Quality Implications

Padmanaban and Krishnan[19] and Arunachalam[20] both document that organic produce from the southern districts often reaches urban distributors in a quality condition that makes it difficult to command organic premiums, not because the produce was grown or certified improperly, but because storage and transportation conditions between farm and market were inadequate. Singh and Dhaliwal[12] demonstrate that even the introduction of basic IoT-based temperature recording devices in refrigerated transport significantly improves quality accountability — a finding suggesting that affordable technology can improve the quality deficit by creating accountability records that incentivise better handling.

6.3 Impact on Farmer Income and Consumer Trust

Krishnamurthy and Balasubramanian[18] document that the 25–40 percent price premium available through direct organic marketing channels is conditional on quality consistency — a condition that storage-constrained farmers cannot reliably meet. Padmanaban and Krishnan[19] quantify that organic farmers who sell at harvest typically receive 30–40 percent less than those who can delay sale by 10–20 days to access premium-willing buyers. Nandi et al.[24] document that urban organic consumers' willingness to pay the premium is strongly conditioned on consistent quality delivery — a condition that storage deficits compromise systemically.

6.4 Scope for Technology-Enabled Storage Management

Aggarwal and Srivastava[23] document successful adoption of digital market and inventory linkage tools by FPOs in comparable Indian smallholder contexts. Wognum et al.[13] argue that transparency systems enabling real-time inventory visibility are a prerequisite for managing organic supply chains effectively. Digital inventory systems at FPO aggregation centres — even in the absence of cold storage — would improve precision in using available storage capacity, reducing avoidable losses from poor stock rotation practice.

6.5 Region-Specific Implications for South Tamil Nadu

The five southern districts present contextual characteristics that make warehousing and storage improvement both particularly urgent and tractable through collective institutional mechanisms. First, crop diversity — organic cotton in Virudhunagar, millets in Madurai and Dindigul, horticultural produce in Tirunelveli and Thoothukudi — means that different storage solutions are relevant for different crops. Second, the presence of PGS-India Regional Councils and active FPOs provides an institutional foundation for collective storage investment. Third, documented consumer demand growth for organic produce in South Indian cities creates a market-demand pull justifying infrastructure investment on commercial viability grounds, given adequate policy facilitation.

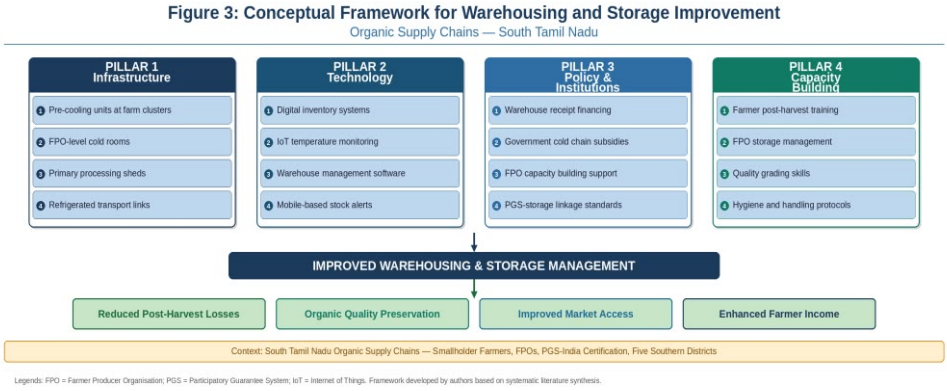

Figure 3: Conceptual Framework for Warehousing and Storage Improvement (South Tamil Nadu Organic Supply Chains)

Legends: *FPO = Farmer Producer Organisation; PGS = Participatory Guarantee System; IoT = Internet of Things. Framework developed by authors based on systematic literature synthesis.*

Table 6: Research Gaps and Future Research Directions

Gap	Gap Description	Evidence Supporting the Gap	Recommended Future Research
G1	No primary empirical study on warehousing specifically in South TN organic supply chains	Available literature addresses Tamil Nadu organics at state level; no district-specific storage study for five southern districts	Mixed-methods field study with organic farmers and FPOs in Madurai, Tirunelveli, Virudhunagar, Thoothukudi, and Dindigul

G2	No evaluation of FPO-level shared warehousing in South TN organic supply chains	SFAC (2023) and NABARD document FPO promotion nationally, but no published evaluation of storage-specific FPO initiatives in the region exists	Longitudinal evaluation of FPO-led pre-cooling and cold room pilot programs in southern TN districts
G3	No crop-specific warehousing study for organic millets, cotton, and horticulture in South TN	Generic post-harvest loss studies do not differentiate by organic certification status or specific crop systems in five southern districts	Crop-specific post-harvest loss audits for organic millet (Madurai/Dindigul), cotton (Virudhunagar), horticulture (Tirunelveli/Thoothukudi)
G4	No feasibility study for warehouse receipt financing linked to PGS-India organic certification	WRS is documented nationally for grains but its application to PGS-certified organic produce has not been studied	Pilot design and feasibility study for WRS linked to PGS-India documentation in Tamil Nadu organic supply chains
G5	No evaluation of digital inventory management adoption in South TN organic FPOs	Literature documents technology adoption potential nationally but no study has tracked digital inventory tool adoption among organic FPOs in five southern districts	Survey-based study tracking digital inventory tool adoption, usage, and impact among FPOs in five southern organic districts

Source: *Authors' gap analysis from thematic synthesis of 28 reviewed sources.*

8. CONCLUSION :

This systematic literature review has examined warehousing and storage challenges and opportunities in organic agri-food supply chains, with particular reference to the South Tamil Nadu context. Drawing on 28 sources retained through a PRISMA-informed screening process, the review identifies a consistent and reinforcing pattern of storage infrastructure deficit that constrains organic supply chain performance from farm gate to consumer.

The five challenge domains — cold storage infrastructure deficit, post-harvest handling losses, organic quality deterioration, inventory management inadequacy, and structural disconnection between storage and market demand — are interconnected dimensions of a systemic infrastructure gap that, when left unaddressed, collectively depresses farmer income, erodes consumer trust, and limits the commercial scalability of organic agriculture in the region. The five corresponding opportunity domains and the four-pillar conceptual framework (Figure 3) together constitute an implementable set of interventions that can be sequenced beginning with the highest-impact, lowest-cost actions.

For South Tamil Nadu specifically, warehousing and storage improvement should be recognised as a central strategic priority directly linked to the agricultural income, quality assurance, and market growth objectives of the region's organic sector. The available literature suggests this is a tractable problem amenable to collective action through FPOs, supported by targeted policy intervention — but that it cannot be resolved without dedicated primary empirical research in the five southern districts.

9. LIMITATIONS:

- Dependence on secondary literature: The review is entirely based on published and grey literature. No primary field data was collected from organic farmers, FPOs, or warehousing service providers in South Tamil Nadu.
- Limited region-specific published studies: The available peer-reviewed literature specifically addressing warehousing and storage challenges in South Tamil Nadu's organic sector is thin. Several conclusions are extrapolated from Tamil Nadu-wide or India-wide evidence.
- Language coverage: Restriction to English-language sources may have excluded Tamil-language extension reports and NGO documentation that could provide more granular regional evidence.
- Evolving technology landscape: The literature on digital inventory management and affordable cold chain technologies is evolving rapidly. Sources published before 2022 may not capture recent advances increasingly accessible in rural India.
- Variability in source quality: The inclusion of grey literature alongside peer-reviewed sources introduces variability in methodological rigour.

10. RECOMMENDATIONS:

- For Organic Farmers: Prioritise immediate post-harvest cooling through low-cost evaporative cool chambers or shaded ventilated storage structures to extend the marketable window by 3-5 days. Adopt mobile-based stock recording to improve batch traceability and inventory visibility.

- For Farmer Producer Organisations (FPOs): Invest collectively in shared pre-cooling units at collection centre level as the single highest-priority storage intervention. Engage with NABARD's FPO promotion schemes and state government cold chain subsidy programs. Implement basic warehouse management protocols including FIFO rotation and daily quality checks.
- For Supply Chain Managers: Design organic supply chain logistics to minimise time between harvest and first cooling at FPO collection centres. Introduce quality and temperature records as standard documentation. Explore shared cold chain logistics arrangements between organic FPOs in adjacent districts.
- For Warehousing Service Providers: Develop organic-compliant warehousing services including mandatory product segregation, documented temperature and humidity management, and certification-compatible inventory records. The premium-paying organic market segment represents a commercially viable case for differentiated warehousing services.
- For Policymakers: Prioritise cold storage infrastructure investment in South Tamil Nadu's five southern districts. Extend warehouse receipt financing schemes to cover PGS-India certified organic produce. Integrate storage infrastructure targets into organic mission district plans for Madurai, Tirunelveli, Virudhunagar, Thoothukudi, and Dindigul.
- For Researchers: Conduct district-level primary field studies on actual post-harvest loss rates by crop type, storage condition, and handling practice. Evaluate the impact of pilot interventions through longitudinal studies tracking loss reduction, quality improvement, and income outcomes over multiple harvest cycles.

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