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Apple horticulture as the backbone of Kashmir's economy: A structural and trade analysis

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Abstract
Apple horticulture is the most visible high-value farm system of Kashmir and a major source of household income, seasonal employment, transport demand, packaging activity, mandi turnover, cold-storage investment and rural credit. This paper develops a public-data assessment of the sector using official and international sources: the NITI Aayog roadmap for horticulture development in Jammu and Kashmir, the J&K Horticulture Department portal, APEDA export information, National Horticulture Board area and production statistics, and USDA/FAS data on India's fresh apple trade. The analysis treats Kashmir's apple economy as a structural production-and-market system rather than as a single crop series. Three results stand out. First, apple dominates the J&K fruit economy: in 2022-23 it accounted for 50.0 percent of all fruit area and 78.8 percent of all fruit production, with even higher shares within fresh fruits. Second, long-run fruit growth has been driven by area expansion and only moderate productivity gains; for apple between 2004-05 and 2022-23, a log-decomposition attributes roughly 69 percent of production growth to area expansion and 31 percent to yield improvement. Third, trade pressure is rising: India's apple imports increased far more rapidly than exports between 2010 and 2024, and USDA/FAS data show imports above half a million tonnes in market year 2024/25. Scenario simulations show that reducing the reported post-harvest apple loss of 500,000 tonnes by 20 percent would recover about 100,000 tonnes and Rs. 300 crores in value, while expanding controlled-atmosphere storage from 270,374 tonnes to 750,000 tonnes would raise coverage from about 12.6 percent to about 34.9 percent of 2022-23 apple output. The paper argues that the strategic constraint is no longer simple output expansion. The central task is coordinated upgrading across rootstocks, grading, farmer-producer organizations, cold-chain logistics, processing, traceability, export protocols and price-risk management.

Keywords: Kashmir, Jammu and Kashmir, apple economy, horticulture; trade, post-harvest losses, controlledatmosphere storage, APEDA, USDA/FAS, public data

Introduction

Apple horticulture occupies a distinctive position in Kashmir's rural economy. It links orchard households to hired labour, wooden and corrugated packaging, transporters, commission agents, cold stores, food processors, retail markets and export channels. The sector has also become a marker of regional identity because the valley's agro-climatic conditions, varietal profile and long commercial history make apples the flagship commodity of high-value agriculture. Official descriptions from the J&K Department of Agriculture and Farmers Welfare identify J&K as India's premier apple-producing region and state that more than 7 lakh families are engaged in horticulture, with annual turnover, employment and man-day generation extending well beyond the orchard gate [2]. The NITI Aayog roadmap similarly treats horticulture as a cornerstone of the J&K economy, with horticulture contributing about 6–7 percent of gross state domestic product, supporting the livelihoods of a large share of the population, and employing millions across the value chain [4].

This paper analyzes apple horticulture as an economic backbone in a structural sense. A backbone sector has four properties. It occupies a large share of the region's productive asset base; it generates broad backward and forward linkages; it anchors rural incomes and employment; and its market risks transmit to households, traders and public policy. Apple satisfies all four conditions. The public statistics used here show that in 2022-23 apple occupied 172 thousand hectares out of 344 thousand hectares under all fruits in J&K and produced 2.146 million tonnes out of 2.722 million tonnes of total fruit output [4]. The same public record shows expansion in controlled-atmosphere storage, food-processing units and e-NAM-linked wholesale markets during 2020-21 to
2023-24, meaning that horticulture is increasingly connected to a broader commercial and logistics ecosystem [4].

The research question is therefore precise: how does public data characterize the structural importance, growth pattern, market infrastructure and trade exposure of Kashmir's apple economy, and what arithmetic scenarios follow for loss reduction, storage expansion and high-density orchard transition? The answer requires combining multiple data layers rather than reading a single production statistic. Production data identify the crop's weight in the economy. Infrastructure data indicate the extent to which commercialization has advanced. Trade data reveal import competition and export opportunities. Scenario analysis converts reported bottlenecks into measurable magnitudes.

The empirical strategy is intentionally conservative. District-level apple trade and price microdata are limited in the public domain, and the NITI roadmap explicitly notes limitations in detailed J&K export statistics. For this reason, the paper uses India-level apple trade data as the relevant external-market context,
while using J&K public tables for area, production, productivity, storage and market-infrastructure indicators. This choice is justified by J&K's dominant share in Indian apple production, which makes India-level apple trade pressure economically relevant for Kashmir's growers, traders and storage investors [4, 6].

The remainder of the paper is organized as follows. Section 2 describes data, notation and methods. Section

3 documents the structural weight of apple horticulture. Section 4 decomposes production growth. Section 5 examines market infrastructure, cold-chain capacity and processing. Section 6 analyzes trade exposure. Section 7 presents simulations. Section 8 draws policy implications. Section 10 concludes.

Data, Definitions, and Methods

1. Public data sources

The analysis uses five public sources. The first is the *Apex Committee Report of 2022 and the resulting Holistic Agriculture Development Program (HADP) of 2023*. It provides long-run fruit area, production and productivity series, crop-level structure for 2004-05 and 2022-23, physical achievements during 2020-21 to 2023-24, market infrastructure, cold storage, food processing and diagnostic statements on post-harvest losses [4]. The second is the J&K Horticulture Department portal, which summarizes official sector facts on apple production, families engaged, turnover and employment [2]. The third is APEDA's fresh-fruits-and-vegetables page, used to situate Kashmir's apple system within India's broader fruit export landscape [1]. The fourth is the National Horticulture Board statistics portal, used as the official horticulture production-statistics source page [3]. The fifth is USDA/FAS India's *Fresh Deciduous Fruit Annual*, used for recent apple import and export quantities by market year [6].

The paper uses the term *Kashmir apple economy* to refer to the valley-centered apple system embedded in the Union Territory-level data reported by official sources. Public tables are reported at J&K or India level. Whenever the analysis moves from J&K production structure to India-level trade, the text states the scale change explicitly.

2. Variables and measurement

Let A_t denote fruit or apple area in year t, Q_t denote production and $y_t = Q_t/A_t$ denote productivity. Area is reported in lakh hectares or thousand hectares, production in lakh tonnes or thousand tonnes, and yield in tonnes per hectare. Let S_t denote controlled-atmosphere storage capacity, E_t denote exported fruit quantity, and R_t denote export revenue. The implied value per tonne is

$$p_t^{\text{imp}} = \frac{R_t}{E_t}, \qquad (1)$$

where R_t is converted from crore rupees into rupees and E_t is converted from lakh tonnes into tonnes. This is an accounting ratio rather than a transaction price. It aggregates all fruits in the official export-revenue table and therefore should be read as a broad value indicator.

3. For production growth, the identity

$$Q_t = A_t y_t \qquad (2)$$

implies the log decomposition

$$\Delta \ln Q = \Delta \ln A + \Delta \ln y. \qquad (3)$$

For apple between 2004-05 and 2022-23, this decomposition measures how much of the proportional increase in output is associated with area expansion and how much is associated with yield improvement. Because this is an accounting decomposition, it carries no causal interpretation by itself. It is nevertheless useful for identifying whether growth is extensive, intensive or mixed. The compound annual growth rate for a variable X_t between an initial year 0 and terminal year T is computed as

$$g_X = \left(\frac{X_T}{X_0}\right)^{1/T} - 1. \qquad (4)$$

For the long-run fruit series, the NITI roadmap reports 1980–2022 CAGRs of 2.33 percent for area, 3.82 percent for production and 1.46 percent for productivity [4]. These values are reproduced in the data file supplied with this paper.

4. Scenario design

The simulations in Section 7 are arithmetic scenarios rather than forecasts. They translate public magnitudes into transparent counterfactuals. The loss-reduction scenario uses the NITI roadmap statement that postharvest apple losses are about 500,000 tonnes with an associated monetary loss of about Rs. 1,500 crores [4]. A loss-reduction rate ρ recovers

$$Q_{\text{rec}}(\rho) = \rho L_Q, \quad V_{\text{rec}}(\rho) = \rho L_V, \qquad (5)$$

where L_Q = 500,000 tonnes and L_V = 1,500 crore rupees. The storage scenario computes the ratio

$$c(S) = 100 \times \frac{S}{Q_{\text{apple},2022-23}}, \qquad (6)$$

where $Q_{\text{apple},2022-23}$ = 2.146 million tonnes. The high-density scenario assumes that a share θ of apple area transitions to a high-density system with proportional yield uplift u, producing incremental output

$$\Delta Q\text{HD} = A\text{apple}\ \theta y\text{base}\ u. \qquad (7)$$

The base values are A_{apple} = 172,000 hectares and y_{base} = 12.5 tonnes per hectare from the 2022-23 crop table. The scenario grid uses $\theta \in \{0.05, 0.10, 0.15\}$ and $u \in \{0.30, 0.50, 0.70\}$. These parameters are illustrative and should be interpreted as policy-planning sensitivities.

Structural Position of Apple Horticulture

The first structural fact is concentration. In 2022-23, apple area was 172 thousand hectares and total fruit area was 344 thousand hectares. Apple therefore represented exactly 50.0 percent of all fruit area in J&K. Apple output was 2.146 million tonnes while all-fruit output was 2.722 million tonnes, giving an all-fruit production share of 78.8 percent. Within fresh fruits, apple represented 68.4 percent of area and 89.2 percent of production. These ratios show that apple is not merely one among many fruits. It is the dominant mass-market fruit crop in the region's recorded horticulture system [4].

The second structural fact is linkage intensity. The J&K Horticulture Department reports more than 7 lakh families engaged in horticulture and identifies annual turnover and employment magnitudes far beyond the orchard boundary [2]. NITI Aayog reports that horticulture supports around 35 lakh people and generates about Rs. 10,000 crores annually [4]. These values should be read as sector-wide horticulture numbers rather than apple-only values, yet apple's production share implies that apple is the principal anchor of those linkages. The apple system generates seasonal demand for pruning, spraying, picking, grading, packing, loading and long-distance transport. It also supports input dealers, cardboard and wooden packaging suppliers, local workshops, bank credit, insurance products, mandi services, storage and retail distribution.

The third structural fact is spatial concentration with systemic risk. A crop that dominates rural cash income creates high upside during favourable seasons and high vulnerability during weather shocks, disease outbreaks, transport disruption, import competition or price collapses. Public policy cannot treat such a crop as an ordinary commodity. Apple price realization affects orchard renewal decisions, household consumption, repayment of seasonal credit, labour demand, storage utilization and confidence in market institutions.

Figure 1 summarizes the concentration profile. The production share is especially striking because apple's all-fruit production share is much larger than its all-fruit area share. This implies a yield and crop-mix advantage relative to several other fruits, while also indicating that any shock to apple quality or market access has aggregate consequences for J&K horticulture.

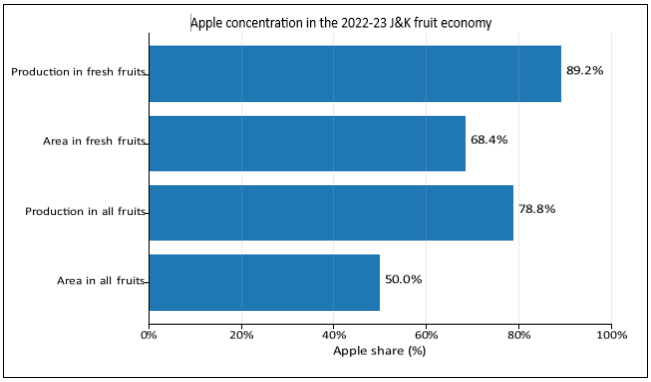

Fig 1: Apple concentration in the J&K fruit economy in 2022-23. Shares are computed from the NITI Aayog crop-structure table. Apple accounts for 50.0 percent of all fruit area and 78.8 percent of all fruit production; within fresh fruits the production share is about 89.2 percent

Production Growth and Productivity Structure

The long-run public series shows strong expansion of the J&K fruit economy. Total fruit area increased from 1.31 lakh hectares in 1980 to 3.44 lakh hectares in 2022. Total fruit production increased from 5.63 lakh tonnes to 27.22 lakh tonnes, while productivity increased from 4.30 tonnes per hectare to 7.91 tonnes per hectare [4]. The NITI roadmap reports the corresponding CAGRs as 2.33 percent for area, 3.82 percent for production and 1.46 percent for productivity. Thus, production growth exceeded area growth because productivity also improved, but the productivity gain was slower than the expansion of cultivated area.

Figure 2 displays this pattern. The fruit economy shifted from a relatively small orchard base in 1980 to a large commercial system by 2022. The years after 2005 show especially visible scale expansion, with production rising from 14.04 lakh tonnes in 2005 to 22.22 lakh tonnes in 2010 and 27.22 lakh tonnes in 2022. Productivity growth is present, yet it is less steep than production growth. This matters for policy because future expansion through land conversion becomes increasingly difficult once suitable land, water availability and orchard-management capacity tighten.

J&K fruit economy: area and production expansion, 1980-2022

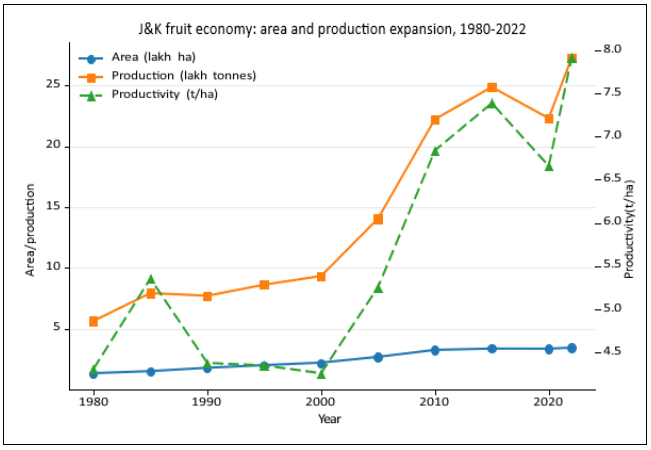

Fig 2: Long-run fruit area, production and productivity in J&K, 1980–2022. The figure uses the NITI Aayog long-run fruit series. Production growth is much stronger than productivity growth, indicating a mixed growth path

with a large extensive component.

The apple-specific change between 2004-05 and 2022-23 confirms the same pattern. Apple area increased from 108 thousand hectares to 172 thousand hectares, a rise of 59.3 percent. Apple output increased from 1.093 million tonnes to 2.146 million tonnes, a rise of 96.3 percent. Apple yield increased from 10.13 tonnes per hectare to 12.50 tonnes per hectare, a rise of 23.4 percent [4]. Applying equation [3], the log change in apple production is approximately 0.675. The log change in area is 0.465 and the log change in yield is 0.210. Area expansion therefore explains about 69 percent of the log output increase, while yield improvement explains about 31 percent.

This decomposition has a clear economic meaning. Kashmir's apple boom was not built solely on yieldenhancing technology. A major part of the increase came from land moving into apple cultivation or from apple orchards reaching productive maturity. The next stage requires an intensive growth strategy: rootstock renewal, canopy management, irrigation, grading, disease control, weather-risk management and post-harvest upgrading. The public roadmap makes a similar diagnosis by emphasizing high-density plantations, rootstock modernization, aggregation hubs, cold chain and processing [4].

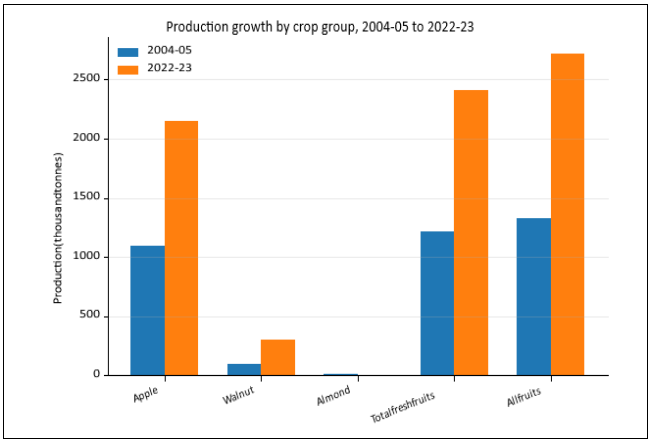

Fig 3: Production growth by selected fruit crop and group, 2004-05 to 2022-23. Apple remains the dominant fresh-crop and accounts for most of the increase in total fruit output.

Table 1 summarizes the apple decomposition. The numbers are simple enough to verify directly from public tables. They also show why productivity is the key variable for long-term competitiveness. Import competition places pressure on quality, size, grading and consistency; productivity measured only in tonnes per hectare does not capture all of these dimensions, yet low productivity growth usually limits the ability to invest in quality upgrading.

Table 1: Apple growth decomposition, 2004-05 to 2022-23

Indicator	2004-05	2022-23	Change
Area (thousand ha)	108.0	172.0	59.3%
Production (thousand tonnes)	1,093.0	2,146.0	96.3%
Yield (tonnes/ha)	10.13	12.50	23.4%
Log contribution of area	–	–	68.98% of $\Delta \ln Q$
Log contribution of yield	–	–	31.16% of $\Delta \ln Q$

Source: Author calculations from the NITI Aayog crop-structure table. Percentages may differ slightly from exact additivity because of rounding in reported table values

Markets, Storage, and Processing

Commercial horticulture depends on the institutions that move fruit from orchards to buyers. Public data show major expansion in J&K's market-infrastructure indicators during 2020-21 to 2023-24. The number of e-NAM-linked mandis increased from 4 to 17. Recorded e-mandi trade value increased from Rs. 0.14 crore to Rs. 416.39 crore. Controlled-atmosphere storage capacity increased from 151,286 tonnes to 270,374 tonnes. Food-processing units increased from 8 to 197 [4]. These changes indicate that the apple economy is becoming more formalized and more linked to modern supply-chain tools.

The pace of change is important. A storage capacity of 270,374 tonnes is a significant improvement, yet it is still only about 12.6 percent of the 2022-23 apple output of 2.146 million tonnes. Storage access is therefore a scarce economic asset. It allows growers and traders to delay sales beyond peak arrival months, reduce distress sales, preserve quality and target higher-price windows. Limited storage coverage concentrates bargaining power among those who can access it and leaves many growers dependent on immediate post-harvest market conditions.

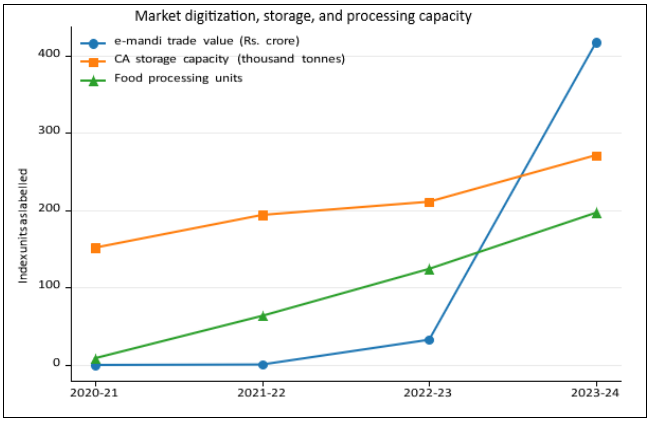

Fig 4: Market digitization, controlled-atmosphere storage and food-processing capacity, 2020-21 to 2023-24. Values are drawn from the NITI Aayog roadmap physical-achievement table

Processing remains a weak link. The NITI roadmap states that major fruit processing in J&K remains low, with apples around 2–3 percent, while post-harvest apple losses are estimated at about 500,000 tonnes and Rs. 1,500 crores [4]. These two figures reveal the core upgrading challenge. When most output is sold as fresh fruit, the sector is exposed to harvest-time gluts, transport bottlenecks, grading limitations and quality rejection. Processing cannot absorb all lower-grade fruit, but a higher processing share can stabilize demand for juice-grade and culled apples, reduce waste and create local value addition.

Export infrastructure also depends on quality systems. APEDA reports that during 2024-25 India exported fresh fruits and vegetables worth USD 1.81856 billion, including fresh fruits worth USD 999.55 million and fresh vegetables worth USD 819 million [1]. Apples are not India's leading fresh-fruit export item; grapes, pomegranates, mangoes, bananas and oranges dominate the fruit export basket according to APEDA. This means that Kashmir apple exports must compete in a national export system where established export protocols, varietal preferences, residue compliance, packaging standards and logistics are already shaped by other fruits. For apples, export upgrading therefore requires commodity-specific work: phytosanitary compliance, uniform grading, carton standardization, cold-chain continuity and market intelligence.

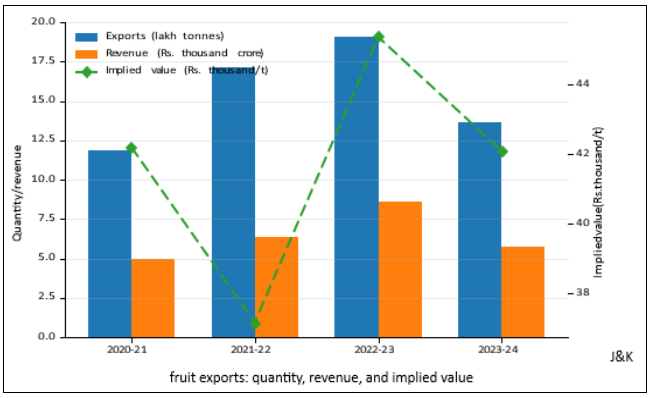

Fig 5: J&K fruit exports: quantity, revenue and implied value per tonne, 2020-21 to 2023-24. The series aggregates fresh and dry fruits in the NITI Aayog physical-achievement table

The J&K fruit-export table shows volatility. Total fruit exports rose from 11.87 lakh tonnes in 2020-21 to

19.05 lakh tonnes in 2022-23, then declined to 13.67 lakh tonnes in 2023-24. Revenue rose from Rs. 5,010 crores to Rs. 8,646 crore and then declined to Rs. 5,756 crores. The implied value per tonne moved within a narrower range, approximately Rs. 37,200 to Rs. 45,400 per tonne. This pattern suggests that annual revenue changes are heavily influenced by volume, with product mix and value per tonne also contributing. Because the official table aggregates fruits, it should not be interpreted as an apple-only export price series.

The market system can therefore be summarized as follows. Production scale has already been achieved. The next constraint is market architecture: sorting, storage, processing, quality certification, aggregation and information. The expansion of e-NAM mandis and CA storage is positive, yet the low processing shares and high loss estimates show that commercialization remains incomplete.

Trade Exposure and Import Pressure

Apple trade analysis has to distinguish between J&K's domestic production dominance and India's external trade balance. Kashmir's growers mostly serve Indian markets, while imported apples compete in quality-sensitive urban retail segments. India-level trade therefore matters because it affects benchmark quality, consumer expectations, price ceilings for premium fruit and investment incentives in storage and grading.

The NITI roadmap reports that India's apple exports increased from 17,170 tonnes in 2010 to 32,874 tonnes in 2024, while imports increased from 122,878 tonnes to 519,652 tonnes. It also reports that apple import value rose from USD 121.3 million to USD 417.6 million, with the trade deficit widening from about USD 108.2 million to about USD 404.5 million [4]. These figures indicate a large external-demand gap. India produces a large volume of apples, and J&K is its main supplier, yet imports have expanded because market demand includes varieties, grades, timing and retail consistency that domestic systems only partly supply.

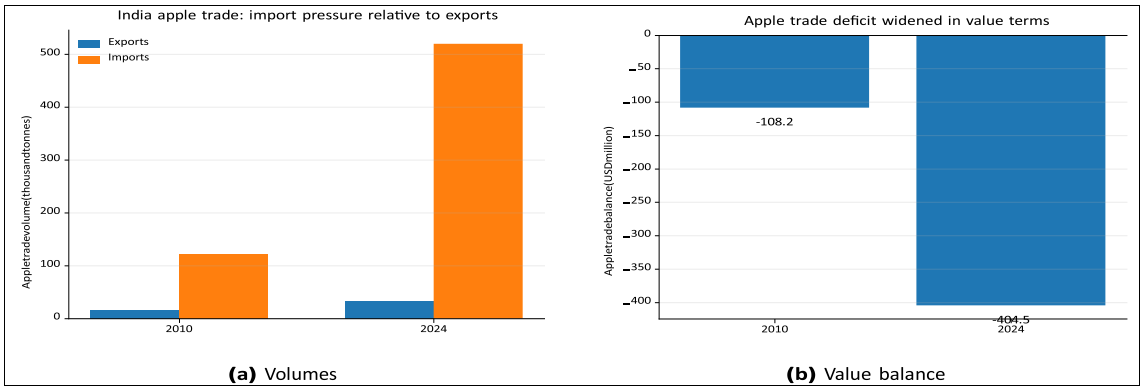

Fig 6: India apple trade, 2010 and 2024. Imports expanded much faster than exports, and the trade deficit widened sharply in value terms

Recent USDA/FAS data reinforces the point. For market year 2024/25, USDA/FAS reports India fresh apple imports of 510,930 tonnes and exports of 34,030 tonnes. Iran, Turkey and Afghanistan were the largest import origins, with Iran alone accounting for about 27 percent of imports [6]. Imports are permitted with a 50 percent basic customs duty and phytosanitary requirements, with no quantitative restriction reported in that USDA/FAS source. The trade regime therefore leaves quality and supply-chain competitiveness as the main domestic response margin.

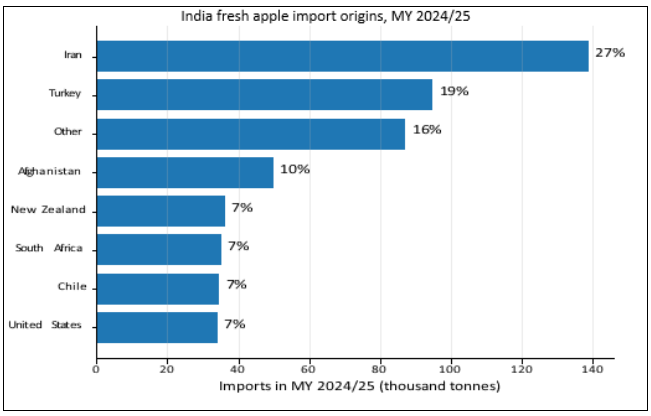

Fig 7: India fresh apple import origins in market year 2024/25. Data are from USDA/FAS. Iran, Turkey and Afghanistan are the largest suppliers by volume

The import data should not be read as a simple displacement story. Imported apples serve particular market windows and consumer segments; domestic apples dominate national availability by volume. The more useful interpretation is that imports reveal where the domestic chain must improve. Imported apples often compete on appearance, grading, shelf life, packaging and reliable supply. If Kashmir's apple chain improves these dimensions, it can defend domestic premium segments and expand outward into regional export markets. If upgrading is slow, imports will continue to set quality benchmarks in urban markets.

Export expansion requires an equally disciplined view. NITI reports that Indian apples are exported to Bangladesh, Nepal, Bhutan, the United Arab Emirates, Saudi Arabia and other destinations [4]. USDA/FAS reports Bangladesh and Nepal as the principal destinations in market year 2024/25 [6]. These are geographically plausible markets for Indian apples, yet export growth requires consistency. Exporters need fruit lots that satisfy size, colour, residue, packaging and documentation requirements. Scattered smallholder production can serve exports only when aggregation, grading and traceability institutions reduce transaction costs.

Trade exposure therefore converts domestic horticulture policy into competitiveness policy. The sector's objective is not only to produce more apples. It must produce apples that can be sorted into distinct value channels: premium fresh domestic, mid-grade domestic, storage-grade, processing-

grade and export-grade. Each channel requires a different mix of logistics, information and institutional support.

Scenario Analysis

This section presents three transparent simulations using public numbers. The aim is to translate bottlenecks into magnitudes that can guide policy discussion. The scenarios do not predict future outcomes; they show what changes in losses, storage and orchard technology would mean under stated assumptions.

Scenario 1: Reducing post-harvest losses

The NITI roadmap reports post-harvest apple losses of about 500,000 tonnes and a monetary loss of about Rs. 1,500 crores [4]. Under equation [5], a 10 percent reduction recovers 50,000 tonnes and Rs. 150 crores. A 20 percent reduction recovers 100,000 tonnes and Rs. 300 crores. A 30 percent reduction recovers 150,000 tonnes and Rs. 450 crores. A 40 percent reduction recovers 200,000 tonnes and Rs. 600 crores. These are large values relative to many public horticulture interventions.

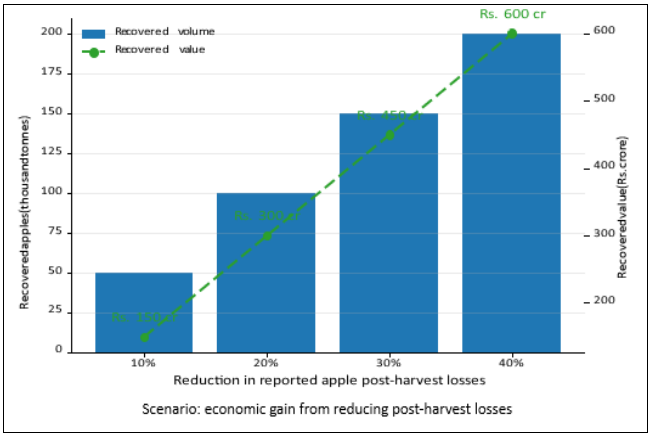

Fig 8: Loss-reduction scenario. The calculation uses a reported apple post-harvest loss base of 500,000 tonnes and Rs. 1,500 crores

The policy interpretation is direct. Loss reduction is a production-equivalent intervention. Saving 100,000 tonnes through better handling, grading, packaging, storage and processing has the same physical effect as producing an additional 100,000 tonnes at the farm gate, while also reducing waste and improving price realization. Loss reduction should therefore be treated as a core growth strategy.

Scenario 2: Expanding controlled-atmosphere storage

Controlled-atmosphere storage capacity reached 270,374 tonnes in 2023-24 according to the NITI physicalachievement table [4]. Relative to 2022-23 apple output of 2.146 million tonnes, this is 12.6 percent coverage. Figure 9 shows coverage under three illustrative capacity targets: 0.50 million tonnes, 0.75 million tonnes and 1.00 million tonnes. The corresponding coverage ratios are about 23.3 percent, 34.9 percent and 46.6 percent of 2022-23 apple output.

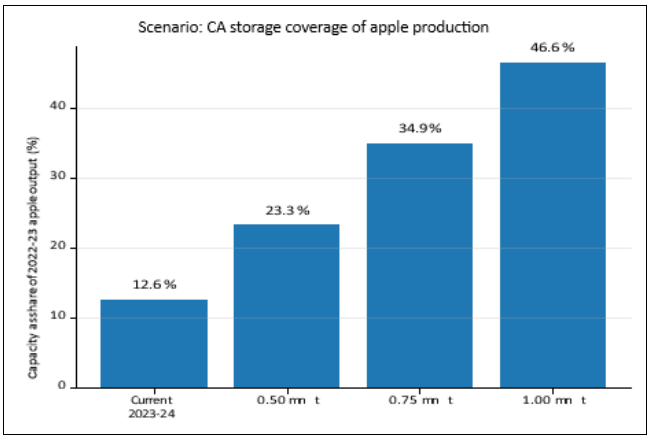

Fig 9: Controlled-atmosphere storage coverage scenario. Coverage is measured against 2022-23 apple output of 2.146 million tonnes

Storage expansion affects the market through several channels. It spreads sales across time, reduces harvesttime congestion, preserves quality, supports grading, and makes export scheduling more feasible. The benefits depend on storage location, energy cost, access for smallholders and integration with packhouses. Storage capacity located far from production clusters or controlled by a narrow set of market actors may have smaller welfare effects for growers. Storage policy therefore needs complementary aggregation and access mechanisms.

Scenario 3: High-density orchard transition

High-density orchards are a central modernization theme in the public roadmap [4]. The scenario in equation [7] measures incremental production if 5, 10 or 15 percent of current apple area transitions to high-density systems and obtains 30, 50 or 70 percent higher yield on the transitioned area. With a base apple area of 172,000 hectares and a base yield of 12.5 tonnes per hectare, the incremental production range is large. A 5 percent area transition with a 30 percent yield uplift adds about 32,250 tonnes. A 15 percent transition with a 70 percent uplift adds about 225,750 tonnes.

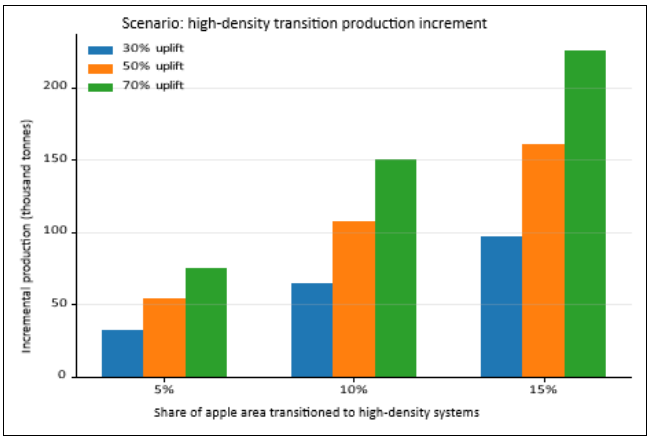

Fig 10: High-density transition scenario. The calculation uses current apple area of 172,000 hectares and base yield of 12.5 tonnes per hectare

The high-density scenario also has a cautionary interpretation. Additional output without storage, grading and processing can intensify market gluts. High-density transition should therefore be sequenced with qualitylinked

market upgrading. The priority is not maximum tonnage alone. The objective is higher marketable yield in quality categories that command better prices and lower losses.

Policy Implications

The structural and trade analysis suggests a seven-part policy agenda.

Productivity and orchard renewal

The production decomposition shows that apple growth has relied heavily on area expansion. Future gains require more intensive productivity and quality improvements. Orchard renewal should prioritize rootstock suitability, disease resistance, canopy design, scientific pruning, pollination management, soil testing, microirrigation and weather advisory systems. Public nurseries and private nursery regulation are crucial because poor planting material locks growers into low performance for many years.

Grading, packing and traceability

Quality heterogeneity reduces returns. A large crop can fetch weak prices when lots are mixed across size, colour, bruising and grade. Packhouses, standard carton specifications, digital lot records and residue-compliance systems can increase trust between growers, traders and buyers. Traceability also matters for exports and premium domestic retail.

Farmer-producer organizations and aggregation

The public roadmap identifies weak farmer-producer organizations and cooperative structures as a constraint [4]. Aggregation is essential because small growers rarely have the volume, information or bargaining power required for direct links with organized retail, processors or exporters. FPOs can coordinate input purchases, grading, storage access and sales timing. Their success depends on professional management and transparent payment systems.

Cold chain with access rules

Storage is a strategic asset. The capacity increase to 270,374 tonnes is a major step, yet coverage remains limited relative to apple output. Public support for storage should include access design: smallholder booking systems, transparent tariffs, geographic dispersion, packhouse integration and credit products that allow growers to delay sales. Without access rules, storage expansion may raise aggregate capacity while leaving many growers exposed to harvest-time price pressure.

Processing and waste reduction

The loss-reduction scenario shows that even a 20 percent reduction in reported losses recovers Rs. 300 crores in value. Processing capacity for juice, concentrate, cider, dried slices, pectin and animal-feed by-products can absorb lower-grade fruit. Processing policy should be tied to quality sorting rather than treated as a residual outlet for unsorted waste. Village-level aggregation and primary processing can reduce transport of low-value

Waste and improve farmer realization.

Trade competitiveness

Import competition reveals the attributes demanded by premium consumers: appearance, size, texture, shelf life, packaging and supply reliability. Export opportunities in Bangladesh, Nepal, the Gulf and neighbouring markets require the same discipline. Trade policy should therefore emphasize export-grade orchards, packhouses, phytosanitary systems, APEDA-linked training, market intelligence and buyer relationships. Tariff protection alone cannot create competitiveness in quality-sensitive markets.

Risk management

Apple incomes are exposed to weather, disease, transport disruption and price volatility. Weather-index products, crop insurance refinement, market-information systems, forward contracts and storage-credit instruments can reduce income volatility. Risk management should be designed around the actual crop calendar: flowering, fruit set, hail risk, harvest arrivals, storage decisions and off-season sales.

Analytical value-chain map for Kashmir apple horticulture

Orchards Aggregation Mandis/e-NAM CA storage Processing/export Retail markets varieties, rootstocks, labourgrading, packing, FPOsprice discoveryseason extension value addimports compete on qualitytion Structural constraint: most value is still captured through fresh-fruit wholesale flows; cold-chain, processing and export readiness determine upgrading.

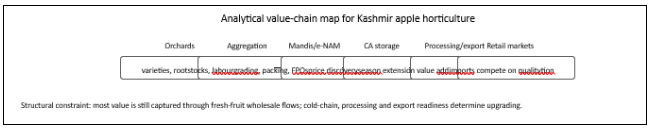

Fig 11: Analytical value-chain map. The main structural constraint is upgrading from fresh-fruit wholesale dependence toward a segmented system with grading, storage, processing and export channels

Discussion

The empirical picture supports a clear conclusion: apple horticulture is already large enough to shape Kashmir's rural economy, but its next development stage depends on structural upgrading. The output base is not the principal weakness. The weaknesses lie in productivity quality, post-harvest management, processing share, storage coverage, aggregation and trade readiness. These constraints are mutually linked. Weak grading reduces storage efficiency. Limited storage increases distress sales. Weak aggregation raises transaction costs for exporters. Low processing capacity increases waste. Import competition exposes domestic quality gaps.

The analysis also highlights a measurement issue. Public data are strong on area, production, storage capacity and broad export quantities, yet weaker on district-level prices, grade-wise arrivals, grower-level margins, storage access, processing utilization and apple-specific export values. Future empirical work should build a district-month panel with variables for mandi arrivals, grade prices, storage inflows, weather shocks, transport disruptions and import arrivals in destination markets. Such a panel would permit causal estimation of storage effects, import pass-through and weather-driven income risk. The present paper provides the structural baseline for that deeper empirical agenda.

A second discussion point concerns sustainability. Apple expansion increases pressure on land, water, pesticide management and soil health. High-density systems can increase marketable output, but they also require careful irrigation, canopy management and input discipline. Sustainable upgrading should combine productivity with

resource efficiency: drip irrigation, integrated pest management, soil organic matter, pollinator support and climate-resilient varieties. Competitiveness and sustainability are linked because residue compliance and quality assurance are increasingly important in premium markets.

A third point concerns employment. Horticulture supports a large number of households and workers, yet modernization can change labour demand. High-density orchards may alter pruning, training and harvest requirements. Packhouses and processing can create non-farm rural jobs, including jobs for women and youth in grading, packaging, quality control and logistics. Policy should therefore evaluate employment not only as orchard labour but as value-chain employment.

Conclusion

Apple horticulture is the backbone of Kashmir's economy because it dominates the fruit production structure, supports a large livelihood base and drives a dense network of market, storage, processing and transport linkages. Public data show that apple accounted for 50.0 percent of all fruit area and 78.8 percent of all fruit production in J&K in 2022-23. Long-run fruit output growth has been impressive, yet the apple decomposition indicates that area expansion has been the larger component of growth. Future competitiveness must therefore come from intensive upgrading.

The trade analysis shows that India's apple imports have grown much faster than exports, with recent USDA/FAS data reporting imports above half a million tonnes in market year 2024/25. For Kashmir, this is a competitiveness signal. Domestic growers can defend and expand market share by improving quality, grading, storage, processing and traceability. The scenario analysis quantifies the stakes. A 20 percent reduction in reported post-harvest apple losses would recover about 100,000 tonnes and Rs. 300 crore. Expanding controlled-atmosphere storage to 750,000 tonnes would raise coverage to about 34.9 percent of 2022-23 apple output. A 10 percent high-density transition with a 50 percent yield uplift would add about 107,500 tonnes, provided market systems can absorb the additional quality output.

The central policy message is that Kashmir's apple economy should be treated as a value-chain system. Production, storage, processing, market information, aggregation and trade access must be planned together.

The public-data evidence points toward a development strategy built on orchard renewal, quality grading, FPO-led aggregation, inclusive cold-chain access, processing expansion, export readiness and risk management. Such a strategy would protect the livelihood function of apple horticulture while raising its competitiveness in an increasingly open and quality-sensitive market.

Reproducibility Note

All figures in this paper are generated by the Python script scripts/make_figures.py using CSV files stored in the data/ directory. The package includes the LaTeX source, compiled PDF, figures in PDF and PNG formats, bibliography file and source-data tables. The scenario outputs are deterministic arithmetic calculations from the public values listed in the data files.

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