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Integrating Ethical Principles, Ecological Balance, and Resource Efficiency: A Sustainable Pathway for Self-Reliance in Pulses and Oilseeds in India

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Abstract:
India's agricultural sector has undergone a significant transformation since independence, achieving self-sufficiency in cereals but continuing to face a critical shortfall in pulses and oilseeds. Despite being the world's fourth largest producer of edible oils, India imports nearly 60% of its oil requirements, with annual imports exceeding 15 million tonnes and draining valuable foreign exchange. Similarly, pulses—an essential protein source for India's largely vegetarian population—continue to be in deficit, leading to dependence on imports. These structural imbalances highlight the urgent need for a sustainable pathway that can enhance domestic productivity, profitability, and resilience in pulses and oilseeds. This paper proposes a framework that integrates ethical principles, ecological balance, and resource efficiency as the foundation for achieving self-reliance in these critical crops. Ethical principles ensure farmer-centric development, equitable value chains, and nutritional security for millions. Ecological balance emphasizes crop diversification, organic farming, agroforestry, and conservation-based practices to restore soil health and biodiversity while mitigating climate change impacts. Resource efficiency highlights circular economy models, water-saving technologies, precision agriculture, and agri-startups utilizing digital innovations such as IoT, GIS, drones, and AI for optimizing input use and reducing wastage. Drawing on historical insights from India's Green Revolution and subsequent policy initiatives, combined with recent evidence on oilseed and pulse production systems, this study underscores the need to reorient agricultural strategies beyond yield maximization toward sustainability and self-reliance. The findings suggest that integrating ethics, ecology, and efficiency can simultaneously address productivity gaps, reduce import dependence, empower smallholders, and align India's agricultural growth with the Sustainable Development Goals (SDGs). This holistic approach positions pulses and oilseeds not merely as commodities, but as strategic crops for food, nutrition, and economic security in 21st century India.

Keywords: Pulses, Oilseeds, Sustainable Agriculture, Resource Efficiency, Ethical Governance

1. Introduction:

Agriculture continues to form the backbone of India's economy, contributing nearly 15–16% to the Gross Value Added (GVA) and providing livelihoods to more than half of the population (Mahesh et al., 2023). Since independence, the country has made remarkable progress in food grain self-sufficiency, particularly through the Green Revolution, which boosted rice and wheat production. However, this

cereal-centric strategy came at the expense of pulses and oilseeds—two crop groups that are vital for ensuring nutritional security, edible oil availability, and ecological sustainability. Pulses are the primary source of plant-based protein for a largely vegetarian population, while oilseeds supply dietary fats and serve multiple industrial applications (Bharti et. al., 2025). Yet, India remains heavily dependent on imports: annual inflows of pulses average over six million tonnes, while edible oil imports surpass fifteen million tonnes, amounting to more than ₹82,000 crores annually (Teja, 2021; Seed World, 2024; ReutersRIS, 2024). This dependency not only strains foreign exchange reserves but also exposes the nation to global price volatility and supply chain disruptions. Pulses and oilseeds are integral to India's food security, nutritional diversity, and farm economy. India is the largest global producer and consumer of pulses, yet continues to rely on imports to meet domestic demand (FAO, 2024). Similarly, in spite of significant oilseed cultivation, edible oil imports account for over 60% of domestic consumption (DAC&FW, 2023).

Despite numerous policy interventions—ranging from the Yellow Revolution and National Food Security Mission to more recent initiatives under Aatmanirbhar Bharat—India has not achieved self-reliance in these commodities. Pulses imports surged to 6.5 million tonnes in 2024–25, marking a 40% increase from the previous year, while domestic production stagnated at 25–26 million tonnes, down from 27.3 million tonnes in 2021–22 (Seed World, 2024). Similarly, edible oils continue to show a structural deficit: although domestic oilseed output increased by 55% between 2014–15 and 2024–25, nearly two-thirds of national demand is still met through imports, including palm, soybean, and sunflower oils (The Economic Times, 2024; News Arena India, 2024). Sunflower oil alone accounted for 3.49 MMT of imports against a total domestic consumption of 3.55 MMT, underscoring the persistent imbalance. These trends reflect systemic barriers such as low crop productivity, fragmented landholdings, inadequate irrigation, declining soil fertility, water stress, climate variability, and insufficient access to technology, credit, and markets (Sukanya, 2024).

The challenges of pulses and oilseed production highlight the limitations of conventional yield-centric strategies that prioritize short-term gains over long-term resilience. Intensive practices without ecological safeguards have resulted in soil degradation, water depletion, and biodiversity loss (Lal, 2020; FAO, 2021; IPBES, 2019). Furthermore, inequities in resource distribution and limited institutional support disadvantage smallholder farmers, who constitute the backbone of these crop systems (Prakash et al., 2024). Achieving self-reliance therefore requires an integrated approach that combines ethical, ecological, and resource-efficient principles. Ethical considerations include inclusivity, fairness, and farmer welfare, with emphasis on gender equity and participatory decision-making in agricultural policy (Gupta, 2009). Ecological balance is equally critical, as pulses contribute to nitrogen fixation and low water use, while diverse oilseed systems can enhance crop rotation and soil health (Gupta et al., 2025). Resource efficiency, through innovations such as precision agriculture, integrated nutrient management, climate-resilient crop varieties, and improved post-harvest handling, is central to reducing environmental footprints while enhancing productivity (Ullah et al., 2024).

Given these complexities, researchers have increasingly turned to methodological frameworks to evaluate sustainability pathways for pulses and oilseeds. Life Cycle Assessment (LCA) and ecological footprint analysis are employed to quantify environmental impacts across production cycles, while Data Envelopment Analysis (DEA) and stochastic frontier models assess farm-level efficiency (Soteriades et al., 2016). Geographical Information Systems (GIS) and remote sensing tools enable spatial monitoring of soil fertility, water availability, and crop health, facilitating site-specific interventions such as

optimized irrigation and variable-rate fertilization (Ullah et al., 2024). Participatory approaches—including farmer surveys, focus groups, and participatory rural appraisals—provide qualitative insights into socio-economic constraints and ethical considerations, ensuring that proposed interventions remain locally relevant and socially acceptable (Defosset, 2014). Integrating these approaches produces robust, evidence-based strategies. For example, DEA studies reveal resource bottlenecks, GIS-driven nutrient mapping reduces fertilizer wastage, and remote sensing aids in proactive pest management. At the same time, LCA captures trade-offs between productivity and ecological footprint, enabling policymakers to balance yield goals with sustainability imperatives.

Methodological approaches to studying self-reliance in pulses and oilseeds have evolved across three main strands of research. First, techno-centric frameworks emphasize digital agriculture, precision farming, IoT, AI, and circular economy practices as tools for resource optimization and productivity enhancement (Mahesh et al., 2023). While these studies highlight efficiency and technological innovation, they often underplay ethical inclusivity and ecological sustainability. Second, historical analyses, such as those by Saha (2025), employ policy and structural evaluations to demonstrate how the Green Revolution and subsequent reforms achieved cereal sufficiency but marginalized pulses and oilseeds, leading to monoculture practices, soil degradation, and vulnerability in rainfed regions. Third, crop- and sector-specific studies (Teja, 2021) adopt production, marketing, and value-chain analyses to examine persistent yield gaps, dependence on rainfed agriculture, post-harvest losses, and price volatility, revealing the vulnerability of smallholder farmers and systemic inefficiencies across procurement and market systems. While each strand contributes valuable insights, they remain fragmented; technological studies focus on efficiency, historical analyses on structural imbalances, and crop-specific studies on micro-level constraints. An integrated methodological framework is therefore needed—one that synthesizes efficiency-oriented, ecological, and ethical perspectives into a cohesive analytical model aligned with the Sustainable Development Goals (SDGs).

Against this backdrop, the present study synthesizes existing methodological literature and empirical evidence to propose an integrated framework for sustainable self-reliance in pulses and oilseeds in India. By embedding ethical governance, ecological stewardship, and resource efficiency into policy and practice, the study seeks to strengthen national food and nutrition security, enhance environmental resilience, and support the socio-economic well-being of smallholder farmers. Such a framework provides not only a conceptual basis for future research but also a practical roadmap for measurable, adaptable, and scalable interventions across India's diverse agro-climatic zones.

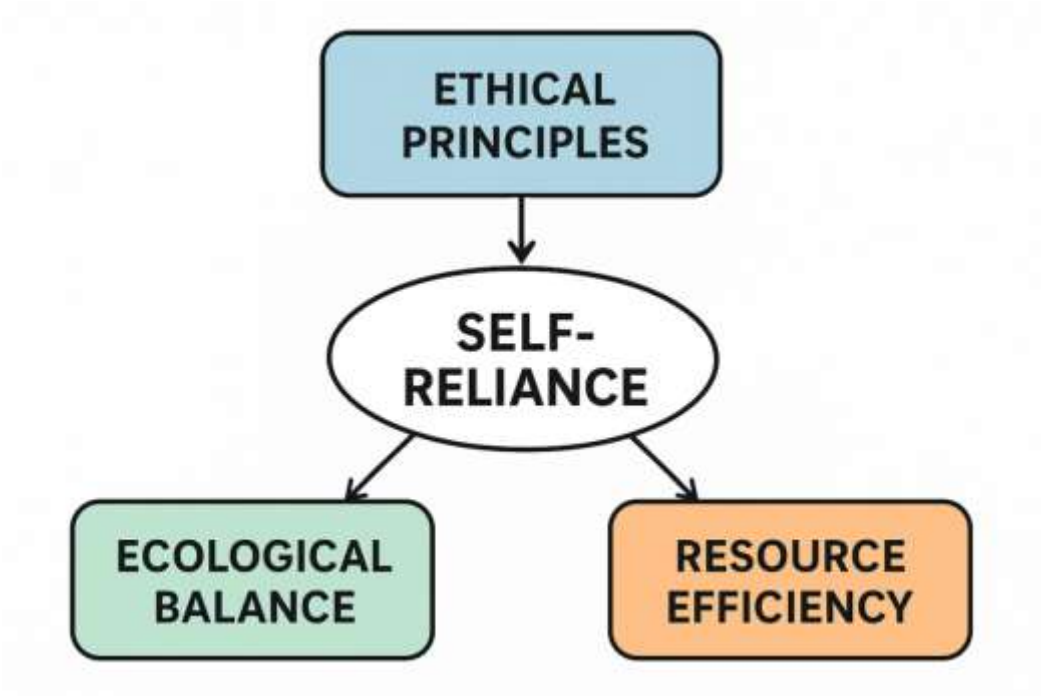

Figure 1: Conceptual Framework

2. Materials and Methods

This article synthesises:

1. **Literature Review** – Peer-reviewed studies (2015–2025) on sustainable pulse and oilseed cultivation, value chain development, and resource management.
2. **Policy Analysis** – Examination of national and state-level agricultural programmes, MSP policies, and sustainability schemes.
3. **Case Examples** – Documentation of field-level innovations, including Farmer Producer Organisation (FPO)-led micro-irrigation models and agroecological crop rotations.
4. **Framework Development** – Integration of findings into a policy-practice model linking ethical governance, ecological balance, and resource efficiency.

The approach follows a narrative synthesis method, enabling thematic categorization of best practices and identification of gaps.

3. Historical Context and Policy Dimensions:

3.1 Historical Context

The trajectory of pulses and oilseed cultivation in India reflects the nation's evolving agricultural priorities since independence. Traditionally, pulses occupied a central role in Indian diets, particularly as a primary source of protein for a largely vegetarian population (Reddy et al., 2010; Ali & Gupta, 2012; Singh et al., 2017). Their cultivation was integrated into mixed and subsistence farming systems, where they contributed to soil fertility through biological nitrogen fixation and complemented cereal production (Ali & Kumar, 2005; Ghosh et al., 2007; Reddy et al., 2010). Oilseeds, including groundnut, mustard, sesame, and linseed, were cultivated extensively in rainfed regions and supported both household consumption and local trade.

However, the advent of the Green Revolution in the 1960s and 1970s shifted national focus predominantly toward cereals such as wheat and rice. High-yielding varieties, irrigation investments,

and subsidized inputs disproportionately favored these crops, resulting in stagnation of pulses and oilseeds production (Shivaji, 2021). During this period, India transformed from a near self-sufficient producer of edible oils to one of the largest global importers (Teja, 2021). The neglect of pulses and oilseeds created structural imbalances: declining area under cultivation, relatively lower productivity, and insufficient research and extension support compared to cereals (Varalakshmi & Reddy, 2020). Despite these setbacks, pulses and oilseeds remained integral to nutritional security, rural livelihoods, and agroecological sustainability. Historical evidence shows that indigenous varieties adapted well to marginal environments, yet received limited policy and research attention. This historical neglect has been a critical factor in India's persistent production–consumption gap, especially in edible oils (Singh et al., 2020).

3.2 Policy Dimensions

Recognizing the growing import dependence and nutritional significance, successive policy interventions sought to revitalize pulses and oilseeds. The Technology Mission on Oilseeds (TMO) launched in 1986 marked a turning point, aiming to boost productivity through improved varieties, extension services, and price support (Chand et al., 2015). Later expanded into the Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM), this initiative reflected a more holistic approach to crop diversification (Government of India, 2007; Chand & Raju, 2015; Singh et al., 2020). Pulses gained prominence in policy discourse in the 2000s, when rising imports and escalating prices highlighted vulnerabilities in domestic supply. The National Food Security Mission (NFSM), initiated in 2007, included a dedicated component for pulses to enhance area, productivity, and production. Targeted programs, such as cluster demonstrations and frontline extension, sought to narrow the yield gaps.

More recently, the Government of India has promoted oil palm under the National Mission on Edible Oils–Oil Palm (NMEO–OP) to reduce import dependence on palm oil, while simultaneously encouraging indigenous oilseeds through improved procurement and Minimum Support Price (MSP) mechanisms (Press Information Bureau, Government of India. 2025). In parallel, international collaborations, public–private partnerships, and value-chain interventions have been emphasized to integrate farmers into processing and marketing systems. Policy emphasis has also shifted toward sustainability. Recent frameworks integrate ecological and resource efficiency considerations, promoting water-use efficiency, soil health management, and climate-resilient varieties (Government of India, 2018; Chand, 2019; FAO, 2021; NITI Aayog, 2022).These dimensions highlight the gradual recognition that pulses and oilseeds are not only essential for dietary needs but also for environmental services and resilient farming systems.

4. Results:

4.1 Production and Import Dynamics

4.1.1 Production Trends

India accounts for nearly 25% of global pulse production and about 12% of global oilseed production. The total area under pulses in India has hovered around 28–30 million hectares, with production increasing from 14 million tonnes in 2009–10 to over 27 million tonnes in 2021–22. This growth has been largely driven by chickpea, which constitutes more than 45% of total pulse production, followed by pigeon pea, urad, mung bean, and lentils. Despite these gains, average yields remain modest at 850–900 kg/ha, compared to the global average of 1,100–1,200 kg/ha.

Oilseed cultivation covers about 26–28 million hectares, with production rising from 18 million tonnes in 1986–87 (the year of the Technology Mission on Oilseeds) to nearly 37 million tonnes in 2021–22. Among oilseeds, soybean and rapeseed–mustard have emerged as dominant crops, accounting for more than 60% of production. Soybean production reached about 12 million tonnes in 2020–21, while rapeseed–mustard contributed 10 million tones. Nevertheless, average oilseed yields remain around 1,200 kg/ha, significantly below global benchmarks of 1,800–2,000 kg/ha.

Table 1: Trends in Pulses and Oilseeds Production, Area, and Import Dependency in India (2014–15 to 2024–25)

Crop / Indicator	2014–15	2019–20	2023–24	2024–25 (Projected)	Change 2014–15 → 2024–25 (%)	Import Dependency (% of Domestic Consumption)
Pulses – Production (MMT)	17.7	23.1	24.5	25.0	+41.2	28–30% (Seed World, 2024)
Area (Million ha)	23.6	26.2	28.1	28.0	+18.6	–
Oilseeds – Production (MMT)	274.0	320.5	415.0	426.1	+55.5	~56% (News Arena India, 2024)
Area (Million ha)	26.0	29.5	34.0	34.2	+31.5	–
Edible Oil Imports (MMT)	9.2	12.1	15.6	16.4	+78.3	~56%
Pulses Imports (MMT)	4.5	5.3	5.8	7.3	+62.2	28–30%

Sources: DAC&FW (2023–24), FAOSTAT, Seed World 2025, News Arena India 2025.

4.1.2 Import Dependence

Despite being a major producer, India is heavily dependent on imports to meet domestic demand. Edible oil imports have surged in the past three decades. In 1993–94, imports stood at less than 1 million tonnes, but by 2021–22, imports had crossed 13.5 million tonnes, meeting nearly 60–65% of domestic consumption. Palm oil constitutes the bulk of imports (around 8–9 million tonnes annually) sourced mainly from Indonesia and Malaysia, while soybean oil (about 3–3.5 million tonnes) is imported from Argentina and Brazil, and sunflower oil (about 2 million tonnes) from Ukraine and Russia.

Pulses imports, though smaller, are strategically important. India imported 2.8 million tonnes of pulses in 2015–16, which declined to around 2.5 million tonnes in 2020–21 due to policy interventions. Major sources include Myanmar (pigeon pea and urad), Canada and Australia (chickpeas and lentils), and the

U.S. (dry peas). Despite increased domestic production, imports continue to constitute 8–10% of total consumption, reflecting structural imbalances between supply and demand.

4.1.3 Drivers of Import Dependence

The persistence of import reliance can be attributed to several interrelated factors. First, per capita pulse consumption in India has increased from 37 grams/day in 2000 to over 50 grams/day in 2020, reflecting both population growth and rising incomes. Second, edible oil consumption has surged from 8 kg per capita in the 1970s to over 19 kg in 2020–21, surpassing domestic production capacity. Third, yield gaps remain substantial: potential yields of pulses and oilseeds are estimated at 1.5–2 times higher than current national averages. Fourth, international competitiveness of imports, combined with tariff liberalization in the 1990s, made imported edible oils cheaper than domestically produced oils.

4.1.4 Emerging Concerns

India's dependence on imports creates vulnerabilities in food security, trade balance, and farmer welfare. Edible oil imports alone cost the exchequer over ₹1.2 lakh crore (US$15–16 billion) annually. Geopolitical disruptions, such as the Russia–Ukraine conflict, led to sharp spikes in sunflower oil prices, while climate shocks in Southeast Asia disrupted palm oil supplies. For pulses, export restrictions from Myanmar and Canada in the past decade have demonstrated the fragility of external reliance. These concerns underscore the urgency of enhancing domestic production through research, innovation, and policy support.

4.2 The Four Pillars of Sustainable Self-Reliance in Pulses and Oilseeds

4.2.1 Ethical Governance

Ethical governance in agriculture refers to a framework that prioritizes equity, inclusivity, and accountability across the entire value chain. In the context of pulses and oilseeds, it involves ensuring that smallholder farmers — who account for the majority of cultivators — have fair access to quality seeds, institutional credit, procurement mechanisms, and remunerative markets (FAO, 2022; Singh & Ramasamy, 2023; Kumar et al., 2021). Historically, policy attention has disproportionately favored cereals, leaving pulses and oilseeds under-supported in terms of investment and extension services. Ethical governance demands corrective measures that safeguard farmer livelihoods, promote gender equity, and enable marginalized communities to participate in decision-making processes.

From a trade perspective, ethical governance also requires balancing consumer affordability with producer incentives. For instance, while import liberalization has ensured price stability for consumers, it has simultaneously weakened domestic producer confidence (Gulati & Saini, 2020; Chand, 2021). Ethical governance frameworks argue for transparent procurement systems, predictable trade policies, and the strengthening of Farmer Producer Organizations (FPOs) to empower cultivators in collective bargaining (World Bank, 2021; Singh & Ramasamy, 2023).

4.2.2 Ecological Balance

Pulses and oilseeds play a central role in maintaining ecological balance. Pulses enrich soils through biological nitrogen fixation, enhance crop rotation systems, and reduce dependence on synthetic fertilizers. Oilseeds such as sesame, groundnut, and mustard thrive in marginal ecologies and are often cultivated under rainfed conditions, contributing to resilience in dryland agriculture (Singh et al., 2021; Reddy & Bantilan, 2020). However, the expansion of monocultures and excessive chemical use has undermined biodiversity, depleted soils, and created vulnerability to climate extremes.

Sustaining ecological balance requires an agroecological approach that integrates pulses and oilseeds into diversified cropping systems alongside cereals and horticultural crops. Conservation agriculture practices, such as minimum tillage, integrated pest management, and crop diversification, can restore ecological functions while sustaining yields. Additionally, the promotion of climate-resilient varieties and organic/natural farming practices offers pathways to safeguard ecosystems while enhancing farm-level productivity (FAO, 2022; Singh et al., 2021).

Table 2: Strategic Pillars, Key Interventions, and Expected Benefits for Sustainable Self- Reliance

Pillar	Key Interventions	Expected Benefits
Ethical Governance	Farmer Producer Organizations (FPOs) - Sustainability-linked MSP - Payments for Ecosystem Services (PES)	Equity in access - Fair market pricing - Improved trust and transparency
Ecological Balance	Legume-based rotations and intercropping - Agroforestry - Soil residue management and organic amendments	Soil fertility restoration - Biodiversity conservation - Resilience to climate variability
Resource Efficiency	Soil health cards and nutrient management - Micro-irrigation and drip systems - Mechanization service hubs	Reduced input costs - Timely farm operations - Increased water and nutrient use efficiency
Integrated Pathway	Pilot districts → scale-up → institutionalization - Policy alignment with sustainability metrics	Synergistic sustainability outcomes Long-term self-reliance - Environmental and social co-benefits

4.2.3 Resource Efficiency

Resource efficiency is pivotal to bridging the widening gap between demand and supply. Productivity levels of pulses in India remain below 1 tonnes/ha, compared to the global average of 1.5–2 tonnes/ha; oilseed yields average 1.2 tonnes/ha, significantly below the global benchmark. This gap highlights the urgent need for efficient utilization of land, water, nutrients, and energy resources. Technologies such as precision farming, micro-irrigation, mechanization, and digital advisory services have shown promising results in enhancing resource-use efficiency (NABARD, 2024; TractorForEveryone, 2024).

Equally important are post-harvest and value-chain efficiencies. It is estimated that 10–15% of pulses and oilseeds are lost annually due to poor storage, inadequate processing infrastructure, and weak logistics. Improving storage, establishing decentralized processing units, and enhancing market connectivity can significantly reduce losses and improve farmer returns (Birthal et al., 2015; Gulati & Sharma, 2019).

Furthermore, by-products of oil extraction, such as oilseed cakes, can be repurposed as livestock feed or soil amendments, reinforcing a circular economy approach.

Table 3. Sustainability performance metrics for pulses and oilseeds in India

Dimension	Indicator	Description/Measurement	Relevance to Pulses and Oilseeds
Ethical Governance	Farmer Participation	Percentage of farmers in FPOs/Cooperatives	Ensures equity, bargaining power, fair markets
	Inclusive Procurement	Share of procurement from small & marginal farmers	Enhances access to MSP and market linkages
	Transparency in Value Chains	Price spread between farm-gate and retail (%)	Reduces exploitation, improves farmer income
Ecological Balance	Soil Health Index	Organic Carbon (%), Nutrient Balance (N:P:K)	Pulses fix nitrogen, oilseeds improve rotation
	Biodiversity Index	Crop diversification ratio (pulses/oilseeds in area)	Maintains agro-ecological resilience
	Water Footprint	m^3 water/kg yield (blue, green water use)	Pulses and oilseeds are low-water demanding
Resource Efficiency	Input-Use Efficiency	Partial Factor Productivity (kg output per kg input)	Reflects optimal use of fertilizers & seeds
	Energy Use Efficiency	Net energy ratio (output energy/input energy)	Shows sustainability of mechanisation
	Carbon Footprint	kg CO_2 eq/ton of output	Evaluates emissions reduction in farming
Socio-Economic Impact	Farmer Income Growth	% increase in real income from pulses & oilseeds	Core indicator for self-reliance goals
	Import Dependency Ratio	Imports ÷ Domestic Consumption (%)	Tracks national self-reliance progress

4.2.4 Integrated Pathway

While each of the three pillars is critical, sustainable self-reliance can only be achieved by integrating them into a coherent strategy. Fragmented interventions — focusing solely on production or trade — have historically delivered suboptimal results. An integrated pathway envisions the simultaneous pursuit of ethical governance, ecological balance, and resource efficiency within policy and practice.

For pulses, this means linking breeding programs for high-yield and biofortified varieties with equitable access to quality seeds, extension, and market opportunities. For oilseeds, integration involves coupling resource-efficient cultivation technologies with transparent procurement systems and value-chain strengthening (Government of India, 2021; NITI Aayog, 2024). Importantly, policy coherence across agriculture, trade, environment, and nutrition sectors is essential to avoid contradictory incentives. An

integrated pathway aligns directly with India's vision of *Atmanirbhar Bharat*, while also supporting global commitments such as the United Nations Sustainable Development Goals. By embedding ethical, ecological, and efficiency dimensions into a unified framework, India can enhance domestic production, reduce import dependence, and simultaneously safeguard farmer livelihoods and ecological sustainability (Chaturvedi, 2025).

4.3 Integrated Implementation Pathway

Achieving self-reliance in pulses and oilseeds requires a phased approach that integrates ethical governance, ecological balance, and resource efficiency into practice. The implementation pathway must be carefully sequenced to generate early momentum, consolidate institutional mechanisms, and embed sustainability within long-term policy frameworks. A three-tier strategy—short, medium, and long term—provides a structured roadmap for operationalizing this vision.

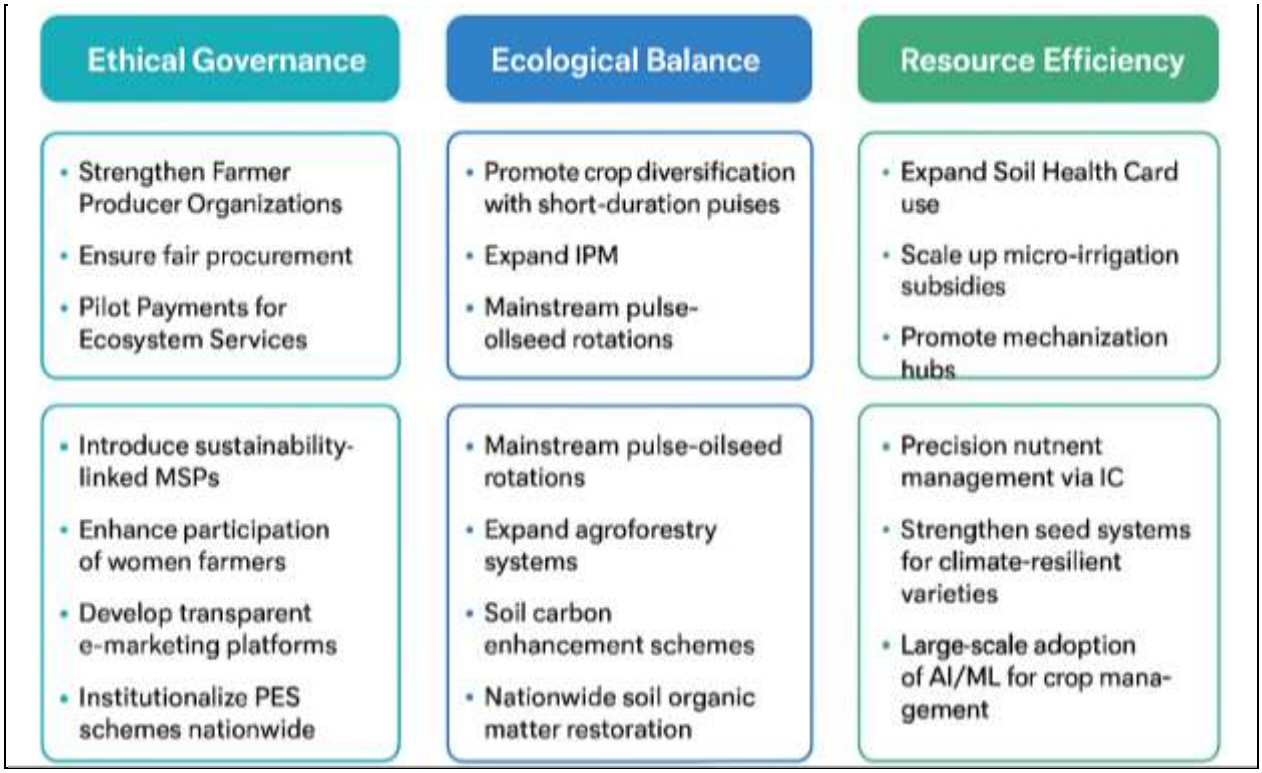

Figure 2: Road Map for Sustainable Self-Reliance in Pulses and Oilseeds

4.3.1 Short Term (1–2 years): Pilot Interventions and Farmer-Centric Hubs

In the immediate phase, targeted pilot districts should be launched to test integrated models of sustainable production and procurement. These pilots would link sustainable procurement systems with Farmer Producer Organization (FPO) service hubs, thereby offering bundled services such as access to quality seeds, soil health testing, customized input packages, and localized extension support. The pilots should also leverage digital platforms for real-time market intelligence and input-output tracking, ensuring transparency and accountability (NABARD, 2022; Singh & Ramasamy, 2023).

By focusing initially on districts with high potential for pulses and oilseeds, these pilots can generate scalable lessons while building confidence among farmers and local institutions. Early evidence from such interventions can also inform subsidy design and extension models at the state and national level.

4.3.2 Medium Term (3–5 years): Scaling, Value-Chain Strengthening, and Policy Alignment

In the medium term, successful pilot models must be scaled up across states, supported by financial incentives and institutional alignment. A key priority will be to realign subsidies—currently skewed toward cereals and chemical inputs—toward sustainability benchmarks such as water-use efficiency, organic/natural farming, and adoption of climate-resilient varieties (NITI Aayog, 2021; Chand, 2021).

Simultaneously, the agro-processing sector must be strengthened to absorb increased production and reduce post-harvest losses. Establishing decentralized processing units, modern storage facilities, and cold chains near production clusters will enable efficient value addition. Integrating FPOs into processing and marketing networks will empower farmers to capture a higher share of value, thereby aligning production incentives with sustainable practices (Joshi & Gulati, 2020; NABARD, 2022). This phase should also focus on capacity building of extension systems, ensuring that ecological farming practices, integrated nutrient management, and mechanization technologies reach farmers in a context-specific manner.

4.3.3 Long Term (5–10 years): Institutionalization and Mainstreaming Sustainability

Over the long term, the goal must be to institutionalize sustainability within core agricultural policy instruments. Minimum Support Price (MSP) and procurement policies should incorporate sustainability criteria, rewarding farmers who adopt resource-efficient and ecologically sound practices (Kumar & Sharma, 2022; Government of India, 2023). This requires the development of measurable indicators and certification frameworks that integrate sustainability into procurement systems.

At the production level, agroecological practices—such as intercropping, integrated pest management and soil conservation—should be mainstreamed, supported by research and extension investments. Moreover, Payments for Ecosystem Services (PES) and resilience metrics can be integrated into agricultural monitoring systems, incentivizing farmers to provide ecological benefits such as carbon sequestration, biodiversity enhancement, and water conservation (FAO, 2022; Wunder et al., 2020). By embedding these principles into long-term governance structures, India can ensure that self-reliance in pulses and oilseeds is not only an economic achievement but also an ethical and ecological milestone.

5. Discussion:

The analysis of India's pulse and oilseed sector underscores both the strategic importance of these crops and the systemic challenges that constrain their growth. Pulses remain indispensable for addressing protein malnutrition, while oilseeds are critical for meeting dietary fat requirements and reducing the country's ballooning edible oil import bill. Yet, despite their nutritional, economic, and ecological relevance, both sectors continue to lag behind cereals in terms of productivity, policy support, and investment priorities.

A key theme emerging from this study is the multidimensionality of sustainability. Ethical governance, ecological balance, and resource efficiency are not standalone pillars but interdependent dimensions. Ethical governance ensures that farmer welfare, equity, and inclusivity remain central to production strategies; ecological balance safeguards long-term soil, water, and biodiversity health; and resource efficiency optimizes input use to maximize output while minimizing externalities. When pursued in isolation, these pillars deliver only partial gains. The proposed integrated implementation pathway highlights how short-, medium-, and long-term interventions can be sequenced to harmonize these dimensions and generate sustained transformation.

The findings also confirm the persistence of structural barriers. Fragmented landholdings, yield gaps, climate vulnerability, and market volatility form a web of constraints that cannot be resolved through singular interventions. For example, expanding MSP coverage without addressing productivity gaps may stabilize farmer incomes but will not reduce import dependence. Similarly, investing in R&D without parallel reforms in procurement and value chains may limit the adoption of improved varieties. This interdependence underscores the necessity of systemic, multi-level approaches that align technology, institutions, and markets.

From a policy perspective, the discussion reveals a tension between short-term food security goals and long-term sustainability objectives. Import liberalization has historically ensured consumer price stability but has weakened domestic production incentives. Conversely, recent attempts to restrict imports have led to short-term inflationary pressures. This suggests that policy design must move beyond binary choices toward balanced frameworks that safeguard both producers and consumers while embedding sustainability benchmarks. The ecological dimension of pulses and oilseeds provides a unique opportunity for India to align agricultural sustainability with climate commitments. By promoting pulses in cereal-based systems, India can reduce fertilizer use, improve soil health, and contribute to low-carbon farming. Similarly, integrating oilseeds into crop rotations enhances biodiversity and strengthens resilience in rainfed systems. However, the widespread adoption of these practices requires robust extension support, R&D investment, and financial incentives, none of which are adequately institutionalized at present.

Finally, the results highlight the need for rethinking metrics of success in the sector. Current evaluations often prioritize production volumes or import substitution, whereas broader indicators—such as farmer welfare, ecosystem services, and climate resilience—remain underexplored. Embedding sustainability indicators into MSP frameworks, procurement policies, and monitoring systems could provide more holistic measures of progress. The discussion illustrates that India's pathway to self-reliance in pulses and oilseeds lies not merely in increasing yields but in integrating ethical, ecological, and efficiency principles into a coherent governance framework. The proposed integrated pathway provides a roadmap for aligning short-term interventions with medium- and long-term sustainability goals. Yet, realizing this vision requires a paradigm shift in agricultural research, policymaking, and value-chain development, supported by sustained political will and stakeholder participation.

6. Challenges and Barriers:

Despite the significant opportunities for enhancing self-reliance in pulses and oilseeds, several structural and systemic barriers continue to impede progress. These challenges span farm-level constraints, institutional gaps, market inefficiencies, and environmental stresses.

6.1 Fragmented Landholdings and Inadequate Infrastructure

The dominance of small and fragmented landholdings in India poses a fundamental barrier to scaling up pulse and oilseed production. Nearly 85% of farmers operate on less than two hectares, limiting their ability to invest in improved seeds, mechanization, and modern irrigation systems. Fragmentation also constrains the adoption of resource-efficient practices such as precision farming, which often require consolidated plots for cost-effectiveness (Joshi & Gulati, 2020; NABARD, 2022). Additionally, post-harvest infrastructure remains inadequate; the lack of modern storage, cold chains, and decentralized processing facilities leads to significant losses and reduces farmer incentives to expand cultivation.

6.2 Yield Gaps and Import Dependence

One of the most pressing challenges is the persistent yield gap. Pulse yields in India average 850–900 kg/ha, compared to the global average of 1,200–1,500 kg/ha, while oilseed yields remain around 1.2 tonnes/ha, far below the international benchmark of 1.8–2 tonnes/ha (FAO, 2022; Government of India, 2023; Gulati & Saini, 2020). This productivity gap directly translates into heavy reliance on imports. India currently imports 60–65% of its edible oil requirement, with palm oil, soybean oil, and sunflower oil dominating the import basket. Pulses, though produced in significant quantities domestically, still require imports of 2–3 million tonnes annually, largely sourced from Myanmar, Canada, and Australia (Chand, 2021; Gulati & Saini, 2020; Government of India, 2023). This dependence undermines food and nutritional security, exposes the economy to global market volatility, and discourages domestic farmers from expanding production.

6.3 Limited Research and Development Investments

Compared to cereals, pulses and oilseeds have historically received lower levels of R&D investment. The Green Revolution era prioritized wheat and rice, leaving pulses and oilseeds with fewer breeding programs, limited access to high-yielding varieties, and weaker extension services (Kumar & Sharma, 2022; Singh & Ramasamy, 2023). While recent initiatives such as the National Food Security Mission have attempted to close these gaps, research in areas such as biofortification, stress tolerance, and disease resistance remains inadequate. Public sector breeding programs are often underfunded, while private sector investment in pulses and oilseeds lags behind that in commercial crops like cotton and maize (Chand, 2021; Gulati & Saini, 2020; Kumar & Sharma, 2022). This imbalance perpetuates productivity stagnation and import reliance.

6.4 Climate Variability and Rainfed Dependence

A significant proportion of oilseed and pulse cultivation occurs in rainfed regions, making them highly vulnerable to climate variability. Erratic rainfall patterns, droughts, and temperature extremes directly affect yields and farmer incomes. For instance, soybean and groundnut are particularly sensitive to rainfall fluctuations, while pigeon pea and lentil yields are affected by terminal heat stress. Climate change projections suggest increasing risks to rainfed agriculture, threatening both productivity and stability of supply (IPCC, 2022; Reddy & Bantilan, 2020; FAO, 2022). Without robust adaptation strategies, including drought-tolerant varieties, improved irrigation coverage, and climate-smart agronomic practices, the vulnerability of these crops will persist.

6.5 Market Volatility and Inadequate MSP Coverage

Market volatility is another critical barrier. Prices of pulses and oilseeds fluctuate widely due to global trade dynamics, speculative trading, and seasonal supply variations. Although Minimum Support Price (MSP) policies exist for both pulses and oilseeds, procurement coverage is limited compared to cereals. For many farmers, the assurance of MSP is more theoretical than practical, as government procurement agencies often lack the capacity or mandate to purchase large volumes of pulses and oilseeds (Chand, 2021; Gulati & Saini, 2020; Government of India, 2023). As a result, farmers remain exposed to market risks, discouraging long-term investment in these crops. Aligning MSP mechanisms with sustainability criteria and expanding procurement coverage are necessary to stabilize farmer incomes and production incentives.

In sum, fragmented landholdings, persistent yield gaps, low R&D investments, climate vulnerability, and unstable markets collectively constrain India's ability to achieve self-reliance in pulses and oilseeds. These barriers are deeply interconnected: weak infrastructure amplifies the risks of climate shocks; low

R&D perpetuates yield gaps; and inadequate MSP frameworks magnify market volatility. Overcoming them requires a coordinated strategy that combines farmer-centric support, scientific innovation, and institutional reforms.

7. Conclusion:

Pulses and oilseeds occupy a central role in India's quest for nutritional security, economic stability, and ecological resilience. Yet, despite their strategic importance, these crops remain constrained by yield gaps, fragmented landholdings, inadequate infrastructure, and dependence on imports. The analysis demonstrates that overcoming these barriers requires more than technological interventions or short-term policy fixes; it demands a systemic transformation grounded in ethical governance, ecological balance, and resource efficiency.

Policy recommendations emerging from this study include:

- Enhanced R&D investments in breeding for high-yielding, biofortified, and climate-resilient varieties of pulses and oilseeds.
- Expansion of MSP coverage and procurement systems with sustainability-linked incentives to stabilize farmer incomes.
- Strengthening FPOs and cooperative structures to improve farmer bargaining power, reduce input costs, and facilitate value-chain integration.
- Mainstreaming ecological farming practices—such as intercropping, integrated nutrient management, and organic/natural farming—into extension services.
- Diversifying import sources while building domestic capacity, reducing vulnerability to global market shocks.

Looking ahead, future research must focus on holistic sustainability indicators, encompassing not only productivity but also farmer welfare, gender inclusivity, ecosystem services, and resilience to climate variability. Such metrics would enable a more balanced assessment of progress and support evidence-based policymaking. In conclusion, self-reliance in pulses and oilseeds is not solely an agricultural target but a broader developmental imperative. By embedding ethics, ecology, and efficiency into policy and practice, India can reduce its import dependence, enhance farmer livelihoods, and contribute to global sustainability goals. The pathway is complex, but with coherent strategies and sustained commitment, it is both achievable and transformative.

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