The State of Indian Agriculture Post-2021: Production, Challenges, and the Path to a Resilient Future

Section I: The State of Indian Agriculture: A Post-2021 Production and Economic Analysis

The Indian agricultural sector, a cornerstone of the national economy and the primary source of livelihood for over half of its workforce, has demonstrated remarkable resilience and productive capacity in the years following 2021. The period has been characterized by record-breaking output in several key crops, reflecting the culmination of policy support, scientific advancements, and the tireless efforts of the farming community. However, this narrative of success is nuanced, with aggregate production figures masking significant sectoral imbalances and underlying economic stresses. A comprehensive analysis of production data, economic contribution, and trade performance reveals a sector at a crossroads, balancing impressive quantitative achievements with pressing challenges in sustainability, profitability, and equitable growth.

1.1. Production Landscape: A Tale of Record Highs and Troubling Lows

The agricultural year 2022-23 stands as a testament to India's production capabilities. According to the Final Estimates released by the Department of Agriculture and Farmers Welfare, total foodgrain production reached an unprecedented 329.68 million tonnes. This represents a substantial increase of 14.07 million tonnes, or 4.46%, over the 315.61 million tonnes produced in 2021-22. This achievement is not merely an incremental gain; it is 30.86 million tonnes higher than the average production of the preceding five years (2017-18 to 2021-22), underscoring a strong upward trajectory in output.[1]

A granular look at crop-specific performance provides a more detailed picture of this growth.

- **Grains and Cereals:** Production of rice, the primary Kharif staple, grew by a robust 4.85%, reaching 135.75 million tonnes in 2022-23, up from 129.47 million tonnes the previous year. Wheat production also saw a healthy increase of 2.61%, rising to 110.55 million tonnes.[1] The most striking growth was observed in nutri-cereals (coarse cereals), which surged by 12.15% to 57.31 million tonnes, with maize production leading the charge at 38.08 million tonnes, a 12.90% increase. This reflects a growing policy and consumer focus on millets and other traditional grains, celebrated during the International Year of Millets in 2023.[1]
- **Oilseeds:** In a significant step towards reducing import dependency on edible oils, the oilseeds sector witnessed remarkable growth of 17.87%, with total production reaching 41.35 million tonnes in 2022-23. This was largely driven by a 15.41% increase in soybean production (14.98 million tonnes) and a 5.69% rise in rapeseed and mustard output (12.64 million tonnes).[1]
- **Commercial Crops:** The positive trend continued in major commercial crops. Sugarcane production increased by 11.63% to 490.53 million tonnes, and cotton production rose by 8.20% to 33.66 million bales (of 170 kg each).[1]
- **The Pulse Deficit:** In stark contrast to the growth in other categories, the production of pulses registered a concerning decline of 4.58%, falling to 26.05 million tonnes in 2022-23 from 27.3 million tonnes in 2021-22. This downturn was particularly severe for Tur (Arhar), which saw its production plummet by 21.56% to 3.31 million tonnes. Gram production also fell by 9.45%.[1] This persistent deficit in a key protein source for a largely vegetarian population highlights a critical structural challenge within the agricultural economy. The policy and price support mechanisms that have successfully boosted cereal production have not been as effective for pulses. The Minimum Support Price (MSP) and robust government procurement infrastructure are heavily concentrated on wheat and rice to supply the Public Distribution System (PDS), creating a powerful economic incentive for farmers to prioritize these crops.[4] Consequently, pulses, which are vital for nutritional security, often become a less remunerative choice, leading to acreage shifts and production shortfalls like the one observed in Tur.
- **Horticulture Sector:** The horticulture sub-sector has emerged as a significant driver of growth, with production consistently surpassing that of foodgrains. In 2021-22, horticulture production was estimated at a record 342.33 million tonnes, indicating a crucial diversification towards high-value crops like fruits and vegetables.[6]

Table 1: Production of Major Crops in India (2021-22 vs. 2022-23)

Crop Category	Crop	2021-22 Production (Million Tonnes)	2022-23 Production (Million Tonnes)	Growth % (YoY)

Food Grains	**Total**	**315.61**	**329.68**	**4.46%**
	Rice	129.47	135.75	4.85%
	Wheat	107.74	110.55	2.61%
	Nutri / Coarse Cereals	51.10	57.31	12.15%
	Maize	33.73	38.08	12.90%
Pulses	**Total**	**27.30**	**26.05**	**-4.58%**
	Tur (Arhar)	4.22	3.31	-21.56%
	Gram	13.54	12.26	-9.45%
Oilseeds	**Total**	**35.08**	**41.35**	**17.87%**
	Groundnut	10.13	10.29	1.58%
	Soybean	12.98	14.98	15.41%
	Rapeseed & Mustard	11.96	12.64	5.69%
Commercial Crops	Sugarcane	439.42	490.53	11.63%
	Cotton*	31.11	33.66	8.20%
	Jute & Mesta**	10.14	9.39	-7.40%

*Source: Department of Agriculture and Farmers Welfare, Final Estimates for 2022-23.[1] Note: *Million bales (of 170 kg each), *

Million bales (of 180 kg each).

1.2. Economic Contribution and Growth Dynamics

Agriculture remains a vital cog in India's economic machinery. During the fiscal year 2022-23, the agriculture and allied sectors contributed approximately 18.4% to the country's Gross Value Added (GVA) at current prices.[2] While this share has declined over the decades with the growth of the services and manufacturing sectors, it still represents a substantial portion of the economy and underscores the sector's systemic importance.

The growth trajectory of agricultural GVA, however, reveals a degree of volatility. While the sector grew by an estimated 4.7% in 2022-23, projections for 2023-24 indicated a significant slowdown to 1.44%.[9] This deceleration points to underlying stresses, including the impact of erratic weather patterns and unfavorable market conditions on rural incomes. This situation illustrates a critical decoupling of production growth from commensurate income growth. Even as farmers produce record harvests, their earnings do not necessarily increase proportionally. This is because high output, particularly for crops not covered by robust procurement, can lead to market gluts and depress prices. Without adequate post-harvest infrastructure like storage and processing facilities, farmers are compelled to sell their produce immediately, making them price-takers in a buyer's market. The slowing GVA growth rate, therefore, suggests that the core economic challenge in Indian agriculture is not merely one of production volume but of value chain efficiency and equitable price realization for the producer.

1.3. Agricultural Trade and Export Performance

On the global stage, India is a formidable agricultural powerhouse. It is the world's largest producer of milk, pulses, and spices, and the second-largest producer of staples like rice and wheat, as well as fruits, vegetables, and cotton.[10] This vast production base provides a strong foundation for exports.

In recent years, India has made significant strides in expanding its agricultural export basket. The value of fresh fruit exports, for instance, grew by 47% between FY20 and FY24, reaching ₹8,431 crore (US$ 986 million).[11] In April 2025, exports of agricultural and processed food products saw a 15% year-on-year increase, driven by strong shipments of rice, meat, and fruits.[11] Key export commodities that are major foreign exchange earners include Basmati and non-Basmati rice (US$ 11.29 billion in FY25), marine products (US$ 6.73 billion), spices (US$ 3.79 billion), and buffalo meat (US$ 3.69 billion).[11] This strong export performance

demonstrates growing competitiveness in global markets and the potential for Indian agriculture to play a larger role in global food supply chains. However, this integration also exposes domestic farmers and consumers to the volatility of international prices and geopolitical events.

Section II: The Indian Farmer: Persistent Challenges and Emerging Threats

Beyond the macroeconomic data of production and trade lies the complex reality of the Indian farmer. The agricultural sector is beset by a host of deep-seated, interconnected challenges that constrain profitability, impede growth, and threaten the long-term viability of farming as a livelihood. These issues range from structural and economic pressures to the escalating and undeniable threat of climate change.

2.1. Structural Impediments to Profitability and Scale

The very structure of Indian agriculture presents formidable barriers to efficiency and prosperity. A defining characteristic is the prevalence of small and fragmented landholdings. According to the Agriculture Census, 86% of farmers in India are classified as small and marginal, operating on less than two hectares of land.[12] This extreme fragmentation makes it difficult to achieve economies of scale, limits the adoption of modern machinery and technology, and significantly weakens the bargaining power of individual farmers in the marketplace.[14]

Furthermore, despite significant investments in irrigation infrastructure, a large portion of Indian agriculture remains dependent on the monsoon. Approximately 55% of the net sown area is rain-fed, making millions of farmers highly vulnerable to the timing and intensity of rainfall.[14] An erratic or failed monsoon can have devastating consequences for crop yields and rural incomes.

Compounding these issues is the chronic inadequacy of post-harvest infrastructure. A lack of sufficient cold storage facilities, warehouses, and efficient rural road networks results in substantial post-harvest losses, estimated to be between 15% and 20% of total food production.[14] This infrastructural gap not only leads to immense food wastage but also forces farmers into distress sales immediately after harvest when market prices are at their lowest,

preventing them from realizing the true value of their produce.[15]

2.2. Economic Pressures and Livelihood Viability

The economic environment for Indian farmers is fraught with uncertainty and pressure. They operate in a system characterized by high price volatility, where market prices for their produce can fluctuate dramatically due to supply-demand dynamics, policy changes, and the influence of intermediaries.[13] Without access to reliable market intelligence, farmers are often unable to make informed decisions about when and where to sell their crops, leaving them susceptible to exploitation.

Simultaneously, the cost of cultivation has been steadily rising. The prices of essential inputs such as quality seeds, fertilizers, pesticides, and machinery have increased, continuously squeezing the already thin profit margins of farmers.[19] This creates a precarious financial situation where a single poor harvest can push a farming household into a crisis.

Access to affordable credit remains a critical challenge. While institutional credit is available, procedural hurdles and the lack of collateral often exclude small and marginal farmers from the formal banking system.[14] This forces them to turn to informal moneylenders, who charge exorbitant interest rates, trapping them in a debilitating cycle of debt. The average debt of an agricultural household is alarmingly high, often multiple times their monthly income, which creates immense mental and financial stress and is a major contributing factor to the tragic phenomenon of farmer suicides in the country.[19]

These challenges are not isolated; they form a self-perpetuating cycle of vulnerability. A farmer with a small, fragmented landholding is inherently less resilient to shocks. A single climate event, such as a localized drought, can wipe out their entire crop and savings. To purchase inputs for the next season, they are often forced to take on high-interest debt from informal sources. This debt burden compels them to sell their produce immediately after harvest at depressed prices to meet their repayment obligations. The resulting low income prevents them from investing in resilience-building measures like micro-irrigation or better storage, ensuring their vulnerability to the next shock. This vicious cycle is at the heart of the agrarian crisis in India.

2.3. The Climate Change Imperative: An Existential Threat

Overlaying these structural and economic challenges is the escalating threat of climate

change, which is no longer a distant prospect but a present-day reality for Indian agriculture. The impacts are being felt across the country through rising temperatures, increasingly erratic monsoon patterns, and a higher frequency and intensity of extreme weather events such as heatwaves, droughts, and floods.[21]

These climatic shifts have a direct and detrimental effect on crop productivity. Scientific projections are stark: a temperature increase of 2.5 to 4.9°C could lead to a decline in wheat yields by as much as 41-52% and rice yields by 32-40%.[21] Heat stress disrupts critical growth stages like flowering and pollination, while unseasonal rains can damage mature grains, leading to significant losses.[21]

Climate change is also accelerating the depletion of the natural resources upon which agriculture depends. It exacerbates water scarcity by altering rainfall patterns and increasing evapotranspiration rates.[24] It contributes to soil degradation and desertification, threatening the long-term fertility of agricultural lands.[9] The accelerated melting of Himalayan glaciers, a direct consequence of global warming, also endangers the supply of meltwater that feeds the major river systems crucial for irrigation in the Indo-Gangetic plains.[17]

Many of these environmental stresses are, in fact, the unintended legacy of the Green Revolution. The intensive, input-heavy agricultural model that was promoted to ensure food security led to widespread monoculture of wheat and rice.[15] This required heavy use of chemical fertilizers and water-intensive flood irrigation, which, over decades, have resulted in the depletion of soil micronutrients, loss of organic carbon, falling groundwater tables, and increased soil salinity.[14] While the Green Revolution successfully averted famine, it inadvertently created a new set of long-term environmental and economic challenges that the current generation of farmers must now confront.

The socio-economic consequences are profound, with small and marginal farmers bearing the brunt of the impact. Lacking the financial resources, technology, or insurance to adapt to changing conditions, they are the most vulnerable to crop failures and income shocks. This is leading to increased rural distress and is becoming a significant driver of climate-induced migration, as farming becomes an increasingly unviable livelihood in the most affected regions.[21]

Table 2: Key Challenges in Indian Agriculture and Corresponding Solutions

Challenge Category	Specific Problem	Proposed Solutions
Structural	Fragmented Land Holdings	Promotion of Farmer Producer Organizations (FPOs) for collective action;

		Land leasing reforms.
	Dependence on Monsoon	Expansion of micro-irrigation (PM Krishi Sinchayee Yojana); Rainwater harvesting and watershed management.
	Inadequate Post-Harvest Infrastructure	Investment in cold chains and warehousing (Agriculture Infrastructure Fund); Improved rural road connectivity.
Economic	Market and Price Volatility	Strengthening of e-NAM for transparent price discovery; Better market intelligence systems for farmers.
	Rising Input Costs	Promotion of Integrated Pest Management (IPM) to reduce pesticide costs; Balanced fertilization based on Soil Health Cards.
	Lack of Access to Credit & Indebtedness	Widening coverage of Kisan Credit Cards (KCC); Financial literacy programs; Strengthening formal credit institutions.
Environmental	Climate Change Impacts (Yield Loss)	Development and adoption of climate-resilient and drought-tolerant crop varieties; Crop insurance (PM Fasal Bima Yojana).
	Water Scarcity	Promotion of water-efficient practices

		like drip and sprinkler irrigation; Cultivation of less water-intensive crops like millets.
	Soil Degradation & Fertility Loss	Promotion of organic farming and sustainable soil management; Reducing overuse of nitrogenous fertilizers.

Source: Synthesized from.[9]

Section III: Agronomic Practices and Crop Management in India

The agricultural tapestry of India is woven from diverse climatic conditions, seasonal rhythms, and a rich heritage of farming systems. Understanding these agronomic fundamentals—the "how" and "when" of cultivation—is essential to contextualize the economic and policy discussions that shape the sector. From the monsoon-driven Kharif season to the winter Rabi crops, and from the intensive commercial farms of the plains to the traditional shifting cultivation of the hills, Indian agriculture is a mosaic of practices tailored to specific environments and socio-economic contexts.

3.1. Cropping Patterns and Seasons: The Rhythms of Indian Agriculture

India's agricultural calendar is primarily defined by three distinct cropping seasons, dictated by the southwest monsoon.[26]

- **Kharif (Monsoon) Season:** This is the most significant agricultural season, commencing with the onset of the monsoon in June-July and concluding with the harvest in September-October. Kharif crops are heavily dependent on rainfall and require warm, wet conditions to thrive. The principal crops of this season are rice, maize, millets (sorghum,

pearl millet), cotton, sugarcane, soybean, groundnut, and pulses like Tur (Arhar).[26]

- **Rabi (Winter) Season:** The Rabi season begins after the monsoon retreats, with sowing taking place in October-November and harvesting in the spring months of March-April. These crops require cooler temperatures for germination and growth and are often cultivated using stored soil moisture or irrigation. The major Rabi crops include wheat, barley, gram, peas, and oilseeds like mustard and rapeseed.[26] The success of the Green Revolution was largely centered on boosting the productivity of Rabi wheat.
- **Zaid (Summer) Season:** This is a short-duration season that fits between the Rabi harvest and the Kharif sowing, from approximately March to June. It is characterized by hot, dry weather. Farmers utilize this period to grow crops that mature quickly, such as watermelon, muskmelon, cucumber, bitter gourd, and various fodder crops, often relying on irrigation.[26]

3.2. Cultivation Profiles of Principal Crops

Each major crop has specific agro-climatic requirements that determine its cultivation regions and management practices.

- **Rice (Oryza sativa):** As a staple food for a majority of the population, rice is the most important Kharif crop. It thrives in a hot and humid climate, requiring temperatures between 22°C and 32°C and high annual rainfall ranging from 150 to 300 cm. It is best suited for deep clayey and loamy soils that can hold water. The major rice-producing states are West Bengal, Punjab, Uttar Pradesh, and Andhra Pradesh.[29]
- **Wheat (Triticum aestivum):** The primary Rabi cereal crop, wheat is crucial for food security in northern and north-western India. It requires a cool growing season with temperatures between 10-15°C at the time of sowing and bright, sunny weather with temperatures of 21-26°C during ripening. It needs moderate rainfall of 75-100 cm and grows best in well-drained, fertile loamy soils. The leading wheat-producing states are Uttar Pradesh, Punjab, Madhya Pradesh, and Haryana.[29]
- **Millets (Sorghum, Pearl Millet, Finger Millet, etc.):** These hardy Kharif crops are highly valued for their climate resilience. They are adapted to arid and semi-arid regions, requiring very little water—often just 25-30% of the amount needed for sugarcane or rice. Millets can grow in poor, shallow soils with minimal fertilizer inputs, making them an ideal and sustainable choice for dryland farming systems. They are also considered "climate-compliant" as they can be cultivated in various seasons.[30]
- **Sugarcane (Saccharum officinarum):** A long-duration Kharif crop, sugarcane is a major commercial crop used for producing sugar, gur (jaggery), and increasingly, ethanol. It requires a hot and humid climate and substantial water throughout its growth cycle. Uttar Pradesh and Maharashtra are the leading producers.[33]

- **Cotton (Gossypium species):** The most important fiber crop, cotton is a Kharif crop grown in regions with moderate rainfall and consistently high temperatures. It is the backbone of India's textile industry. The major cotton-producing states are Gujarat and Maharashtra.[29]

The successful cultivation of these crops is heavily dependent on providing the right inputs at the right time, which is dictated by their specific growth stages. A plant's life cycle typically involves germination, a vegetative phase (root and shoot growth), a reproductive phase (flowering and fruit/grain formation), and maturation.[35] Each stage has critical requirements for water and nutrients. For example, for wheat, the "Crown Root Initiation" stage is the most critical for irrigation, while for pulses, the flowering and pod-filling stages are paramount.[36] A failure to meet these stage-specific needs can severely impact the final yield. This underscores the importance of timely and accurate agricultural advisory services, a domain where modern AgriTech solutions can play a transformative role by delivering hyper-local, real-time guidance to farmers.

3.3. A Survey of Regional Farming Systems

India's vast geography and diverse cultures have given rise to a variety of farming systems, each adapted to local conditions.

- **Subsistence Farming:** This is the most prevalent system, practiced by a majority of small and marginal farmers. The primary objective is to grow food for family consumption, with little to no surplus for the market. It typically involves traditional methods, manual labor, and reliance on rainfall.[37]
- **Commercial Farming:** Characterized by large-scale production of crops for sale in the market, this system is profit-oriented. It often involves mechanization, high-yielding variety seeds, chemical fertilizers, and irrigation. It is common in states like Punjab, Haryana, Gujarat, and Maharashtra, focusing on crops like wheat, cotton, and sugarcane.[37]
- **Plantation Farming:** This is a form of commercial farming where a single cash crop, such as tea, coffee, rubber, or spices, is cultivated on a large estate. It is capital-intensive and often geared towards the export market.[37]
- **Shifting Cultivation (Jhum or Podu):** An ancient tribal practice, particularly in the northeastern states and parts of Odisha. A patch of forest is cleared and burned, and the ash fertilizes the soil for a few years. Once the soil fertility declines, the farmers move to a new plot, allowing the old one to regenerate. This system is used to grow crops like maize, root vegetables, and millets.[37]

The dominant agricultural paradigm, however, reflects a significant mismatch between policy

and practice. Government policies, through subsidies for fertilizers and power, and a procurement system focused on MSP for wheat and rice, have overwhelmingly promoted a high-input, water-intensive model of farming.[4] This has inadvertently marginalized traditional, climate-resilient farming systems, particularly those based on millets in dryland areas. The decline in the area under millet cultivation is a direct consequence of this policy bias, which has favored water-guzzling crops even in water-scarce regions, undermining the long-term ecological sustainability of Indian agriculture.[30]

Section IV: Modern Input Management: Fertilizers, Pests, and Diseases

The productivity of Indian agriculture is intrinsically linked to the management of key inputs—primarily soil nutrients and the control of pests and diseases. The post-Green Revolution era has been defined by a heavy reliance on chemical inputs to drive yield growth. However, the long-term consequences of this approach—soil degradation, environmental pollution, and rising cultivation costs—have necessitated a paradigm shift towards more sustainable, efficient, and knowledge-intensive input management strategies. This section examines the current state of fertilizer use, soil health initiatives, and the transition towards Integrated Pest Management (IPM).

4.1. Nutrient Management and Soil Health

Effective nutrient management is the foundation of productive agriculture. However, practices in India have been characterized by significant imbalances, leading to deteriorating soil health across large parts of the country.

- **Fertilizer Recommendations and Imbalance:** For decades, a generalized recommendation for the ratio of Nitrogen (N), Phosphorus (P), and Potassium (K) has been propagated as 4:2:1. However, extensive research has shown that this one-size-fits-all norm lacks a sound scientific basis for India's diverse agro-climatic zones and cropping patterns.[41] The optimal NPK ratio is highly specific to the soil type and the crop being grown. The actual fertilizer consumption pattern in India is heavily skewed towards nitrogenous fertilizers, primarily urea. In 2012-13, the national average NPK consumption ratio stood at 8.2:3.2:1, a severe imbalance driven by a subsidy regime that has historically made urea significantly cheaper than phosphatic and potassic fertilizers.[41] This subsidy-induced overuse of urea is a principal cause of declining soil

fertility, as it depletes other essential micro and macronutrients and can increase soil acidity over time. This practice not only leads to diminishing returns on fertilizer application but also contributes to nitrous oxide emissions, a potent greenhouse gas, thereby linking a domestic subsidy policy to global climate change concerns.[42]

- **The Soil Health Card (SHC) Scheme:** To address this critical issue of nutrient imbalance, the Government of India launched the Soil Health Card Scheme. The scheme's objective is to provide every farmer with a detailed report of their soil's nutrient status for 12 key parameters (including N, P, K, Sulphur, Zinc, and Organic Carbon) and to offer customized, crop-specific fertilizer recommendations.[43] Since its inception, over 25 crore Soil Health Cards have been distributed. The scheme has been technologically upgraded with a GIS-enabled portal and a mobile application for geo-tagged soil sample collection, ensuring greater accuracy and transparency.[43] Studies have indicated that the adoption of SHC recommendations can lead to an 8-10% reduction in chemical fertilizer use and a 5-6% increase in crop yields, demonstrating its potential to promote both economic and environmental sustainability.[45]
- **Organic vs. Chemical Fertilizers:** There is a growing movement towards organic farming, prompting a closer examination of the trade-offs between chemical and organic fertilizers.
    - **Chemical Fertilizers:** Offer a lower upfront cost and provide nutrients in a readily available form for plants. However, their long-term, indiscriminate use can degrade soil structure, harm beneficial microbial populations, and lead to water pollution through nutrient runoff.[46]
    - **Organic Fertilizers:** These include materials like compost, vermicompost, animal manure, and green manure crops. While they may have a higher initial cost per unit of nutrient, they offer significant long-term benefits. They release nutrients slowly, improve soil structure and water retention capacity, and foster a healthy soil microbiome. Over time, this can lead to more resilient crops and reduce the need for external chemical inputs.[46] The Indian organic fertilizer market reflects this growing interest and is projected to expand from US$ 622.6 million in 2025 to over US$ 1 billion by 2032.[48] The government is also promoting organic alternatives through various schemes and by providing market development assistance for manure produced under the GOBARdhan initiative.[49]

4.2. Pest and Disease Landscape

Crop losses due to pests and diseases are a major constraint on agricultural productivity in India, with climate change altering their incidence and geographical spread.[50]

- **Common Crop Diseases and Pests:** A wide range of pathogens affects India's principal

crops.
    - **Rice:** Is highly susceptible to Rice Blast, a devastating fungal disease, as well as Bacterial Leaf Blight, False Smut (also known as "rich man's disease"), and viral infections like Tungro Virus and Southern Rice Black-Streaked Dwarf Virus (SRBSDV), colloquially termed the "Chinese virus".[51]
    - **Wheat:** Suffers from fungal rusts, including Leaf Rust and Stripe Rust, and Powdery Mildew, which can cause significant yield reductions if not managed in a timely manner.[56]
    - **Other Crops:** A host of other diseases affect horticultural and commercial crops, such as early and late blight in potatoes and tomatoes, and various forms of rot and wilt in other vegetables and cash crops.[61]
- **Integrated Pest Management (IPM): A Sustainable Strategy:** In response to the economic and environmental costs of excessive pesticide use, Integrated Pest Management (IPM) is being promoted as a more sustainable and effective approach. IPM is a holistic, eco-friendly strategy that integrates multiple control tactics—cultural, mechanical, biological, and chemical—to manage pest populations and keep them below economically damaging levels.[63]
    - **IPM Techniques:** Key IPM practices include:
        - **Cultural Control:** Using techniques like crop rotation, timely planting, and maintaining field sanitation to disrupt pest life cycles.
        - **Mechanical Control:** Physically removing pests through methods like hand-picking or using traps (e.g., yellow sticky traps for aphids, pheromone traps for moths).
        - **Biological Control:** Conserving and augmenting natural enemies of pests, such as predators (ladybugs) and parasitoids.
        - **Judicious Chemical Use:** Using chemical pesticides as a last resort, preferring bio-pesticides or plant-based pesticides, and applying them based on monitoring and economic thresholds rather than on a fixed schedule.
    - **Benefits of IPM:** The adoption of IPM is often perceived as an environmental choice, but its most compelling advantage for farmers is economic. By significantly reducing the reliance on expensive chemical pesticides—with reductions reported between 40% and 81% in various demonstrations—IPM directly lowers the cost of cultivation.[66] This cost saving, combined with stable or even increased crop yields (reported increases of 8% to 43%), leads to higher net returns and improved profitability for farmers.[66] Therefore, promoting IPM is a direct and powerful strategy for enhancing farmer livelihoods and breaking the cycle of high input costs and debt.

Section V: The Market Ecosystem: Prices, Trends, and Influencing Factors

The economic viability of Indian agriculture is ultimately determined in the marketplace. For farmers, the journey from sowing to selling is fraught with uncertainty, governed by a complex interplay of government price support policies, dynamic market forces, and a host of external factors that influence food prices. An analysis of this market ecosystem post-2021 reveals a landscape of both structured support and significant volatility, where policy intent often diverges from on-the-ground reality.

5.1. Price Support and Discovery Mechanisms

The government employs several mechanisms to ensure price stability and provide a financial safety net for farmers.

- **Minimum Support Price (MSP) Framework:** The MSP is the cornerstone of India's agricultural price policy. The government announces MSPs for 22 mandated crops before each sowing season based on the recommendations of the Commission for Agricultural Costs & Prices (CACP). The stated policy objective since 2018-19 has been to fix the MSP at a level of at least 1.5 times the all-India weighted average cost of production.[4] For the 2023-24 marketing season, the MSP for common paddy was set at ₹2,183 per quintal, and for wheat, it was ₹2,275 per quintal, representing significant nominal increases over previous years.[4]

However, the efficacy of the MSP regime is a subject of intense debate. While MSPs are announced for a wide range of crops, large-scale, effective procurement by government agencies is predominantly limited to paddy and wheat. This is because the procurement of these staples is essential for maintaining the buffer stock required for the nation's Public Distribution System (PDS).[4] For most other crops, such as pulses and oilseeds, government procurement is often sporadic and geographically limited. Consequently, for a majority of farmers growing these crops, the MSP serves more as a theoretical benchmark than an assured price. They are often compelled to sell their produce in open markets (mandis) at prices significantly below the announced MSP, especially during periods of bumper harvest. This reality creates what can be termed the "MSP illusion" and reinforces the economic logic for farmers to continue cultivating wheat and paddy, linking back to the production paradox of surplus grains and deficit pulses.

- **Market Price Discovery: AGMARKNET and e-NAM:** To enhance transparency and improve price discovery, the government has established digital platforms.
    - **AGMARKNET (Agricultural Marketing Information Network):** This portal serves as a national information network, disseminating daily wholesale market prices—including minimum, maximum, and modal prices—for hundreds of

commodities from thousands of mandis across the country.[69]

- **e-NAM (National Agriculture Market):** Launched in 2016, e-NAM is a pan-India electronic trading portal that aims to create a unified national market for agricultural commodities. By connecting existing APMC (mandi) networks, it facilitates transparent, online auctions, allowing farmers to potentially access a wider pool of buyers and achieve better prices. Over 1,400 mandis have been integrated into the e-NAM platform.[25] Analysis of price data from these platforms, such as the monthly modal prices for wheat, reveals significant seasonal fluctuations. Prices typically peak in the lean months before the harvest (e.g., January-February 2025 for wheat) and then decline sharply as the new crop arrives in the market (March-April 2025).[73]

Table 4: Minimum Support Prices (MSP) for Key Crops (Marketing Season 2022-23 & 2023-24)

Crop	Variety	MSP 2022-23 (₹ per quintal)	MSP 2023-24 (₹ per quintal)	Increase (₹)
KHARIF CROPS				
Paddy	Common	2040	2183	143
	Grade 'A'	2060	2203	143
Jowar	Hybrid	2970	3180	210
Bajra		2350	2500	150
Maize		1962	2090	128
Tur (Arhar)		6600	7000	400
Moong		7755	8558	803
Groundnut		5850	6377	527
Soyabean (yellow)		4300	4600	300

Cotton	Medium Staple	6080	6620	540
RABI CROPS				
Wheat		2125	2275	150
Barley		1735	1850	115
Gram		5335	5440	105
Masur (Lentil)		6000	6425	425
Rapeseed & Mustard		5450	5650	200

Source: Press Information Bureau, Government of India.[4]

5.2. Drivers of Food Price Volatility Post-2021

Food inflation has been a persistent concern, driven by a combination of domestic and international factors. A key observation is the divergence in price behavior between two distinct "baskets" of food items. Cereal prices have remained relatively stable due to the government's large buffer stocks and its ability to intervene in the market through the PDS and open market sales.[74] In contrast, the prices of non-cereals, particularly perishables like fruits and vegetables, have been highly volatile. This volatility stems from their fragmented supply chains, a severe lack of cold storage infrastructure, and high susceptibility to localized weather shocks and transport disruptions.[74] This dichotomy means that while India has achieved security in its staple food supply, it continues to struggle with ensuring nutritional price stability, which disproportionately harms low-income households.

The primary drivers of this volatility include:

- **Supply Chain Disruptions:** The after-effects of the COVID-19 pandemic and subsequent logistical bottlenecks have continued to impact the smooth flow of agricultural goods from farm to market, leading to price spikes, especially for perishable items.[74]
- **Climate and Weather Events:** Extreme weather, such as the erratic monsoon of 2023, directly impacts harvests and creates supply shocks. Unseasonal rains or heatwaves can

decimate vegetable and fruit crops, leading to sudden and sharp increases in their prices.[75]

- **Global Factors:** The interconnectedness of global markets means that international events have a direct bearing on domestic prices. Rising global prices for crude oil increase the cost of transportation and the production cost of nitrogenous fertilizers, which are then passed on to consumers. Geopolitical conflicts, such as the war in Ukraine, disrupt global supply chains for grains and fertilizers, further influencing domestic market sentiment and prices.[75]
- **Government Interventions:** To manage domestic inflation, the government frequently employs policy tools such as imposing stock limits on traders, banning exports of sensitive commodities like onions and wheat, and conducting open market sales from its buffer stocks to cool down prices.[75]

5.3. Emerging Market and Consumer Trends

The Indian agricultural market is also being shaped by evolving consumer preferences. A significant trend is the rising demand for organic and high-value agricultural products. Driven by increasing urbanization, higher disposable incomes, and growing health and wellness consciousness, consumers are showing a greater preference for organic foods, fresh fruits, and diverse vegetables. The organic food segment in India is projected to grow at a compound annual growth rate (CAGR) of over 25% between 2022 and 2027, indicating a substantial market opportunity.[11]

On the policy front, there are considerations to deepen and widen the commodity derivatives market. Proposals to allow greater participation from institutional investors like banks and insurance funds aim to increase market liquidity, which could lead to more efficient price discovery and provide better hedging tools for farmers and other stakeholders in the value chain to manage price risk.[79]

Section VI: The Path Forward: Solutions, Innovations, and Policy Support

Addressing the multifaceted challenges confronting Indian agriculture requires a concerted, forward-looking strategy that integrates technological innovation, genetic advancements, robust policy support, and a fundamental shift towards sustainability. The path to a resilient

and profitable agricultural future lies in moving beyond piecemeal interventions to create a holistic ecosystem that empowers farmers, particularly the small and marginal, with the tools, knowledge, and financial security needed to thrive in an increasingly complex environment.

6.1. The AgriTech Revolution: Digitizing Indian Agriculture

Technology is emerging as a powerful catalyst for transforming Indian agriculture from a resource-intensive to a knowledge-intensive sector.

- **Precision Farming and Data-Driven Decisions:** The adoption of modern AgriTech tools is enabling a shift towards precision agriculture. Technologies such as Artificial Intelligence (AI), Geographic Information Systems (GIS), remote sensing via satellites, and drones are providing farmers with unprecedented access to real-time, hyperlocal data. This data on weather forecasts, soil moisture levels, and crop health allows for the precise and efficient application of inputs like water and fertilizers, optimizing resource use and reducing costs.[11]
- **AI for Pest and Disease Management:** One of the most impactful applications of AI is in the early detection and diagnosis of crop pests and diseases. AI-powered mobile applications, such as Plantix, allow farmers to simply take a photograph of an affected plant leaf to receive an instant diagnosis and treatment recommendation, often in their local language. These systems are trained on vast image datasets and have demonstrated accuracy rates of up to 92%.[81] The development and public availability of large, curated image datasets of crop diseases are critical for improving the accuracy and reach of these transformative tools.[83]
- **Digital Infrastructure and Platforms:** At the national level, the government is building a foundational digital infrastructure through initiatives like AgriStack. This project aims to create a unified platform for agriculture by creating a federated database of farmers linked with land records. Such a digital architecture is intended to improve the planning, monitoring, and targeted delivery of government schemes and services.[87]

6.2. Genetic Advancements and Crop Resilience

Scientific research in crop genetics is pivotal for developing new plant varieties that can meet the dual challenges of increasing productivity and adapting to climate change.

- **High-Yielding Varieties (HYVs):** The Indian Council of Agricultural Research (ICAR) and the Indian Agricultural Research Institute (IARI) continue to be at the forefront of

developing HYVs. Between 2014 and late 2022, the National Agricultural Research System released over 2,500 new varieties and hybrids of field and horticultural crops, which have been instrumental in pushing productivity levels to new heights.[6]

- **Climate-Resilient and Biofortified Varieties:** Recognizing the threat of climate change and the challenge of malnutrition, the focus of plant breeding has decisively shifted towards developing "smart" crops. These new varieties are bred for specific traits such as tolerance to drought, heat, and soil salinity. In a landmark event in August 2024, 109 new crop varieties were released, all of which were high-yielding, climate-resilient, and biofortified with essential micronutrients like iron and zinc.[89] These advancements are crucial for ensuring food and nutritional security in a changing climate.
- **Best Practices in Research and Development:** To accelerate the adoption of these innovations, a "lab to land" approach is being emphasized. Programs like 'Mera Gaon Mera Gaurav' (MGMG) are designed to increase the interface between scientists and farmers, facilitating a faster and more effective transfer of technology and new crop varieties from research institutions to the fields.[88]

6.3. Government Schemes and Policy Framework: A Critical Assessment

The Government of India has implemented a wide array of schemes aimed at supporting farmers through direct income transfers, risk mitigation, and infrastructure development.

- **Income Support - Pradhan Mantri Kisan Samman Nidhi (PM-KISAN):** This flagship central sector scheme provides direct financial support of ₹6,000 per year, in three equal installments, to all landholding farmer families. The funds are transferred directly into the beneficiaries' bank accounts via Direct Benefit Transfer (DBT) to ensure transparency. Since its launch in 2019, the scheme has disbursed over ₹3.69 lakh crore through 19 installments.[94] To improve accessibility, a dedicated mobile app has been launched, featuring a face authentication mechanism for e-KYC, which is particularly beneficial for farmers in remote areas.[96]
- **Risk Mitigation - Pradhan Mantri Fasal Bima Yojana (PMFBY):** This is the government's principal crop insurance scheme, offering comprehensive risk coverage against yield losses due to non-preventable natural calamities, pests, and diseases. It covers the entire crop cycle from pre-sowing to post-harvest. The scheme is designed to be affordable for farmers, with very low premium rates (2% of the sum insured for Kharif crops, 1.5% for Rabi crops, and 5% for commercial/horticultural crops), with the remaining premium being subsidized by the government.[99] Initially compulsory for loanee farmers, the scheme was made voluntary for all in 2020. It is increasingly leveraging technology, such as drones and satellite imagery, for more accurate and timely crop loss

assessment and claim settlement.[101]

- **Infrastructure and Credit Subsidies:** The **Agriculture Infrastructure Fund (AIF)** is a financing facility aimed at creating post-harvest management infrastructure and community farming assets. It provides medium- to long-term debt financing with interest subvention.[72] The
  Interest Subvention Scheme (ISS) ensures the availability of short-term agricultural credit at a concessional rate for farmers through the Kisan Credit Card (KCC) scheme.[87]

While these schemes are impressive in their scale and ambition, their on-ground impact is often hampered by a lack of integration and last-mile delivery challenges. A farmer might receive a Soil Health Card recommending a balanced use of fertilizers but finds it more economical to overuse subsidized urea. A new climate-resilient seed variety is developed in a lab, but it may take years to reach the farmer due to inefficiencies in the seed multiplication and distribution chain.[90] The central challenge, therefore, is not the absence of solutions but the failure to weave these disparate programs and technologies into a single, cohesive, and user-friendly support system for the smallholder farmer.

6.4. Strategic Recommendations for a Sustainable Future

The future of Indian agriculture hinges on a paradigm shift from being input-intensive to knowledge-intensive. The most promising and sustainable solutions—IPM, precision agriculture, organic farming, and balanced fertilization based on soil tests—all require a higher degree of knowledge and skill on the part of the farmer. This highlights a critical gap: the agricultural extension system, which is responsible for disseminating this knowledge, is currently under-resourced and needs significant revitalization.[93] Long-term resilience will depend less on the quantum of subsidies and more on the effectiveness of these knowledge transfer mechanisms.

Based on the comprehensive analysis, the following strategic recommendations are proposed:

1. **Policy Re-alignment for Sustainability:** The structure of agricultural subsidies must be reformed. The focus should shift away from input-based subsidies (especially for urea and power) that encourage wasteful consumption and environmental degradation, towards direct benefit transfers (like an enhanced PM-KISAN) and investments in capital assets and sustainable infrastructure. This includes greater funding for micro-irrigation, cold chain logistics, watershed management, and the promotion of renewable energy in agriculture.
2. **Strengthening Farmer Producer Organizations (FPOs):** FPOs are a critical institutional mechanism to overcome the limitations of small, fragmented landholdings. Policy support

should be intensified to help FPOs achieve scale in procurement of inputs, adoption of technology and mechanization, post-harvest processing, and direct marketing. This will enhance their collective bargaining power and improve their members' access to markets and credit.

3. **Integrated Implementation of Schemes:** A concerted effort is needed to ensure convergence and integration between various government schemes. For instance, data from the Soil Health Card scheme should be linked with the PMFBY for more accurate risk assessment and with credit schemes to finance the application of recommended nutrients. This would create a truly holistic support ecosystem where each program reinforces the others.
4. **Investment in R&D and a Revitalized Extension System:** Public and private investment in agricultural R&D must be increased, with a clear focus on developing climate-resilient crop varieties, water-saving technologies, and scalable packages for organic farming and IPM. Crucially, this must be paired with a massive overhaul and strengthening of the agricultural extension system, leveraging digital tools and public-private partnerships to ensure that these innovations and best practices effectively reach every farmer in the country.

Table 5: Overview and Assessment of Major Government Schemes for Farmers

Scheme Name	Objective	Key Features/Benefits	Recent Progress/Status (Post-2021)
Pradhan Mantri Kisan Samman Nidhi (PM-KISAN)	To supplement the financial needs and augment the income of all landholding farmer families.	Provides ₹6,000 per year in three equal installments directly into farmers' bank accounts via DBT.	Over ₹3.69 lakh crore disbursed in 19 installments. Mobile app with face authentication e-KYC launched. The 20th installment of ₹20,500 crore was scheduled for release in August 2025 to 9.7 crore farmers.[95]
Pradhan Mantri Fasal Bima Yojana (PMFBY)	To provide comprehensive crop insurance	Affordable farmer premium (1.5-2% for food crops, 5%	Over 55 crore farmer applications insured since 2016.

	coverage and financial support to farmers in the event of crop failure.	for commercial). Covers risks from pre-sowing to post-harvest. Now voluntary for all farmers.	Increased use of technology (drones, satellites) for loss assessment. Enrolment increased by 27% in FY 2023-24.[99]
Agriculture Infrastructure Fund (AIF)	To provide medium-long term debt financing for investment in post-harvest management infrastructure and community farming assets.	Provides interest subvention of 3% per annum up to a limit of ₹2 crore for a maximum period of 7 years.	As of late 2023, ₹32,042 crore sanctioned for over 42,000 projects, mobilizing an investment of ₹54,487 crore.[87] As of Dec 2024, ₹52,738 crore sanctioned for over 87,500 projects.[72]
Interest Subvention Scheme (ISS) / Kisan Credit Card (KCC)	To provide short-term crop loans at concessional interest rates to farmers.	Provides short-term loans up to ₹3 lakh at an effective interest rate of 4% per annum for prompt repayment.	A saturation drive launched in 2020 has sanctioned 482.73 lakh new KCCs with a credit limit of ₹5,47,819 crore as of Oct 2023.[87]
National Mission on Edible Oil-Oil Palm (NMEO-OP)	To promote oil palm cultivation to increase self-sufficiency in edible oils.	Aims to bring an additional 6.5 lakh hectares under oil palm cultivation between 2021-22 and 2025-26.	The scheme is ongoing with a focus on North-Eastern states and Andaman & Nicobar Islands.[87]