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PRESIDENTIAL ADDRESS

# Advancing Sustainable Growth in Indian Agriculture: Integrating Technology, Market and Policy Frameworks*

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***Honourable Dignitaries, Distinguished Delegates, Ladies and Gentlemen***

With a heart full of gratitude and humility, I stand before you today as the conference president of the Indian Society of Agricultural Economics. I feel elated and deeply honoured by this opportunity, and I would like to extend my heartfelt thanks to all the esteemed members of the society, its president, Dr. D.K. Marothia, and the executive members, whose trust and support have made this moment possible. My deepest gratitude extends further to Dr. D.K. Marothia, who was always available for discussions in organizing the conference. His personal touch and exceptional skills in coordinating the affairs of this conference were truly unmatched.

Reflecting on my journey, I am reminded of my high school days in the sands of district Bathinda in Punjab, where I completed my matriculation. Standing here now, before this distinguished gathering of agricultural economists, feels nothing short of a dream come true.

My path as an agricultural economist has been profoundly shaped by the guidance of Dr S.S. Johl, whose mentorship was a beacon that helped me find my way, and I am indebted to him. I am deeply grateful to Dr B.S. Dhillon, former Vice Chancellor of PAU, whose inspiring leadership guided me in discharging my administrative responsibilities at PAU while continually encouraging me in my academic pursuits. Personal encouragement and continued motivation by Dr Ramesh Chand, a member of NITI Aayog, inspired me to continue learning and remain engaged in research. Today, I also fondly remember my association with my favourite student and esteemed colleague, Dr. Kamal Vatta, who has stood by me steadfastly for the past 20 years through achievements and challenges and whose invaluable contributions have been instrumental in every step of my academic journey. I would be remiss if I did not acknowledge Punjab Agricultural University (PAU), my *alma mater*, which not only provided me with my livelihood but opened doors to other higher seats of learning that broadened my understanding and knowledge.

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Today, I will speak on "Advancing Sustainable Growth in Indian Agriculture: Integrating Technology, Markets and Policy Frameworks," a subject as complex as it is pressing, marked by our country's diverse socio-economic landscape and the influences of domestic and global factors. I thank Dr. D.K. Marothia for his invaluable suggestions as I prepared for this address. I am also profoundly thankful for the help and support of Dr. R.P. Singh and Dr. P.S. Birthal in preparing this address. However, if I fall short of the high standards set by the distinguished figures who have delivered this address in the past before me, I ask for your patience.

## I

## INTRODUCTION

Agriculture has always been a cornerstone of the Indian economy, providing food security for its vast population while employing millions nationwide. Despite the rapid development in other sectors, such as services and manufacturing, agriculture remains the backbone of rural India. Its importance extends beyond food production as it is pivotal in economic stability, employment generation, and rural development.

Historically, agriculture has evolved from a subsistence activity to a structured economic sector, thanks to its major transformation in the form of the Green Revolution of the 1960s. Before independence, Indian agriculture was primarily characterized by small-scale farming with traditional tools and techniques. Agricultural productivity was low, and farmers were heavily dependent on monsoon rains. The Great Bengal Famine of 1943, in which millions died, underscored the vulnerabilities of the agricultural sector under colonial rule. At the time of independence in 1947, India faced severe food shortages and was dependent on food imports. The government's immediate focus was on achieving food self-sufficiency. Consequently, a series of land reforms and agricultural development programs were launched, which included community development programs and cooperatives to increase productivity through better land management and shared resources. However, these early efforts were insufficient to address the deep-rooted problems in Indian agriculture.

The Green Revolution of the 1960s marked a watershed moment in Indian agriculture. Triggered by severe food shortages and a growing population, the government initiated several agricultural reforms to increase food production. The introduction of high-yielding seeds of wheat and rice, alongside various production and protection technologies, transformed the agricultural landscape. Several factors contributed to this transformation. A major one was the expansion of irrigation, facilitated by strengthening the canal network and promoting tubewell irrigation through rural electrification and easy loans. As new high-yielding varieties responded favourably to fertilizers under irrigated conditions, the government prioritized expanding the irrigated area and using chemical fertilisers. Institutional support was equally vital. Establishing State Agricultural Universities (SAUs) such as those in Pantnagar and Ludhiana in 1962 ensured a continuous flow of new varieties and technologies. Simultaneously, agricultural infrastructure, such as rural roads and markets, were developed, linking rural areas with markets and providing access to inputs and output markets. Assured prices in the form of MSP and procurement through the Food Corporation of India (FCI) further ensured that farmers received remunerative prices for their produce. Institutional credit at a low interest rate also played a crucial role by enabling farmers to adopt new technologies and facilitating private agricultural investments.

The happening of the Green Revolution enabled the country to shift from a food-deficit nation to one that is self-sufficient and, eventually, a global exporter of key commodities like rice. Its initial success was concentrated in regions with well-developed irrigation infrastructure, such as Punjab, Haryana, and parts of western Uttar Pradesh. Wheat and rice production surged, and by the 1970s, India no longer needed to rely on food aid.

Economic liberalization during the 1990s brought new opportunities and challenges to Indian agriculture. It increased agricultural exports, particularly in horticulture, fisheries, and livestock. The diversification of the agricultural sector into high-value crops, such as fruits, vegetables, and flowers, provided farmers with new income opportunities. However, this period also saw the growing influence of global markets, exposing Indian farmers to price volatility and competition from international producers. In recent years, technological innovations are further transforming the agriculture sector of India. Adopting precision agriculture, biotechnology, and digital tools like mobile apps and online platforms has provided farmers with new ways to improve productivity, reduce input costs, and access markets. National Agriculture Market (e-NAM) and mobile apps like Kisan Suvidha have empowered farmers by providing real-time information on market prices, weather forecasts, and government schemes. These initiatives help bridge the information gap that has historically disadvantaged small farmers in rural areas.

The success of Indian agriculture can be seen in a tremendous increase in the production of key crops. Rice production increased from 45.9 million tons in 1965-66 to 193.24 million tons in 2021-22, and wheat production grew from 10.40 million tons to 107.74 million tons respectively, with foodgrain production rising from 101 million tons to 322 million tons over the same period. Similarly, pulses, oilseeds, and cotton production witnessed remarkable growth. However, while intensive agriculture laid the foundation for significant agricultural productivity and production gains, it also introduced long-term economic and environmental challenges that persist to this day.

Central to the agricultural discourse today is both economic and environmental sustainability. The economic sustainability of farmers, particularly smallholders who form more than 85% of the farming community, is threatened due to low farm incomes, rising debts, and farmer suicides. Meanwhile, environmental sustainability has become equally pressing as the intensive agricultural practices in food-producing regions have led to the depletion of groundwater reserves, degradation of soil health, and air pollution caused by stubble burning.

My address delves into these multifaceted issues, examining the factors responsible for economic and environmental challenges. A humble effort is also made to present a roadmap for necessary reforms in technology, markets, institutions, and policy frameworks to accelerate agricultural growth while ensuring long-term sustainability.

## II

## ECONOMIC CHALLENGES AND SUSTAINABILITY OF FARMERS

Indian agriculture is predominantly smallholder-based, with over 85 per cent of farmers classified as small and marginal, owning less than two hectares of land. These farmers form the backbone of the agricultural sector, yet they face significant economic challenges that threaten their livelihoods and the sustainability of farming as a viable occupation.

### *2.1 Low and Decelerating Farm Incomes*

One of the most pressing challenges in Indian agriculture today is the economic sustenance of farmers due to low farm incomes. The average monthly nominal income of agricultural households was estimated at Rs 10218 in 2018-19 (NSO, 2021), and real income at 2011-12 prices Rs 6335 only. The growth in farm income was also slow despite a sizeable increase in agricultural output over the past couple of decades. While nominal farm income increased from Rs 2115 in 2002-03 to Rs 10218 per month in 2018-19 (Table 1), growth in real income has not only been small but also decelerated in recent years. The real monthly income increased from Rs 5847 in 2012-13 to Rs 6335 in 2018-19 at the simple rate of 1.39 per cent/annum. Recently published NABARD estimates show some improvement in income at Rs 13661[2] per month in 2021-22 in nominal terms and Rs 7228 in real terms (NABARD, 2024). However, the real income of agricultural households registered a deceleration in its growth over time; the average annual rate of the increase came down from 3.1 per cent from 2002-03 to 2012-13 to 2.6 per cent from 2012-13 to 2021-22. Rising costs of inputs like seeds, fertilizers, pesticides, machinery, and irrigation have outpaced the prices that farmers receive for their produce. However, the most critical concern was the decline in real income from crop production, which fell from Rs 2801 in 2012-13 to Rs 2368 in 2021-22, at an annual rate of 1.72 per cent, showing that the farming during the last about a decade has become un-remunerative. It is the most unwarranted trend that must be addressed at the policy level on priority.

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[2]NABARD estimated average monthly income of Rs 13661 per agricultural household. Rs 4476 (33 per cent) came from crop production, Rs 1677 (12 per cent) from livestock rearing, Rs 2010 (15 per cent) from other enterprises, Rs 2238 (16 per cent) from wage labour and Rs 3150 (23 per cent) from government/private service.

Over time, the composition of income sources has also changed. In 2002-03, major sources of income were crop production and wages, while in 2018-19, the contribution of non-farm business and animal husbandry increased. However, crop production and wages remained a major contributor to total income, reflecting structural changes in the rural economy.

TABLE 1. BREAK UP OF AVERAGE MONTHLY INCOME OF AGRICULTURAL HOUSEHOLDS INTO DIFFERENT COMPONENTS FOR THE YEARS 2002-03, 2012-13, 2018-19 (Rs.)

| Year | Income from Wages | Income from Crop Production | Income from Animal Husbandry | Income from Non-farm Business | Income from Other Sources | Nominal Income | Real Income (at 2011-12 prices) |
|---|---|---|---|---|---|---|---|
| 2002-03 | 975 (46.1) | 969 (45.8) | 91 (4.3) | 39 (1.8) | 41 (2.0) | 2115 | 4459 |
| 2012-13 | 2071 (32.2) | 3081 (47.9) | 763 (11.9) | 512 (8.0) | 71 (1.1) | 6426 | 5847 |
| 2018-19 | 4063 (39.8) | 3798 (37.2) | 1582 (15.5) | 641 (6.3) | 134 (1.3) | 10218 | 6335 |
| Average income of small and marginal farm households, 2018-19 | | | | | | | |
| 2018-19 | 4067 (44.5) | 2875 (31.5) | 1444 (15.8) | 631 (6.9) | 116 (1.3) | 9135 | 5674 |

Note: Figures in parentheses are percentages of the total income
Source: Situation Assessment Surveys of Agricultural Households, National Statistical Organisation, Different rounds

### *2.2 Land Fragmentation and Small Landholdings*

Farm size continues to shrink due to land division, from 1.5 hectares in 1981 to 1.08 in 2016 and 0.74 ha in 2021, making it difficult to achieve economies of scale. Small and marginal farmers are also disproportionately affected by their limited access to credit, technology, and mechanization. Due to the high upfront costs and perceived risks, they are less likely to invest in high-value crops or modern irrigation systems. This perpetuates a cycle of low productivity and low incomes, further marginalizing the smallholders. Many farmers rely heavily on non-farm activities and livestock farming to supplement their income. Their primary source of income is wages (NSSO, 2019). Ranganathan and Pandey (2018) also found that most of the smallholders relied on non-farm sources of income to sustain their livelihood. Birthal *et al.* (2020) found that more than 50 per cent of the income of smallholders in rainfed areas came from livestock and rural non-farm employment. They emphasised the importance of diversified income sources to mitigate income volatility and improve their livelihood.

### *2.3 Farmers' Debt and Financial Distress*

Indebtedness is another significant challenge facing Indian farmers, particularly smallholders. The indebted agricultural households were 55.4 per cent, with an average outstanding debt of Rs 91231 in 2021-22 at all-India level (NABARD, 2024). Most farmers rely on credit to finance agricultural activities, but access to institutional credit is often limited, especially for those with small landholdings. As a result, many farmers are forced to turn to informal credit sources, such as moneylenders, who charge exorbitant interest rates. The inability to repay these loans due to crop failures or poor market prices traps farmers in a cycle of debt, leading to severe financial distress. The burden of debt has had devastating consequences for many farming households, particularly in states like Maharashtra, Andhra Pradesh, and Punjab, where farmer suicides have been widely reported.

### *2.4 Inefficient Agricultural Produce Markets*

Agricultural produce markets, in general, are fragmented and inefficient, involving a large number of intermediaries involved in the supply chain. The lack of integrated markets and value chains results in price disparities, limited market access, and post-harvest losses. Further, poor rural infrastructure, including roads and market linkages, hampers market access. Prices across time and space fluctuate, leading to income uncertainty affecting farmers' financial stability and investments (Gandhi and Koshy, 2006). Few traders control markets and lack post-harvest management facilities. Supply chains are fragmented and involve many links between producer and consumer, causing higher transaction costs. Further, the perishability of the produce, particularly in fruits and vegetables, compels the producer to sell produce immediately after the harvest, whatever the price be. Consequently, the producer's share in the consumer’s rupee is much less. The share for field crops is relatively higher compared to perishable crops. For wheat and rice, it generally ranges between 58 and 66 per cent (Acharya, 1997), while for fruits and vegetables, it often ranges between 25 and 40 per cent (Reardon *et al.*, 2012). In the recently conducted RBI studies, producer share was estimated at 31 per cent for tomato, 36 per cent for onion, and 37 per cent for potato (Roy *et al.,* 2024). In fruits, farmers receive 31 per cent of the consumer’s price for banana, 35 per cent for grapes, and 43 per cent for mango (Das *et al.*, 2024), while in pulses, farmers receive 75 per cent of chickpea price, 70 per cent of moong and 65 per cent of pigeon pea (Jose *et al.,* 2024). This is primarily due to higher marketing costs, wastage, and longer value chains. A smaller share creates a disincentive for the expansion of the production of crops. The more serious issue is that there is no improvement in the producer share over time, indicating the persistence of inefficiencies in agriculture markets and supply chains. Poor and unscientific storage facilities and un-refrigerated transportation further aggravate the problem. Multiple intermediaries in the supply chain cause a higher level of wastage. It has been estimated that wastage is as high as 12.44 per cent in vegetables and 15.88 per cent in fruits. These are 6 per cent in cereals and 8.41 per cent in pulses (Jha *et al.*, 2015).

### *2.5 Inadequate Market Access*

Market access is critical for Indian farmers, particularly those in remote or underserved regions. Most farmers still sell their produce in local markets, where they are subject to the whims of middlemen and traders who often offer prices far below the Minimum Support Price. Regardless of market conditions, they are usually forced to sell their produce immediately after harvest due to lacking capital, inadequate storage facilities, and cold chain infrastructure for perishable crops such as fruits and vegetables. The fragmentation of agricultural markets also exacerbates inefficiencies in the supply chain.

*2.6 Productivity Gaps*

Technological advancements have been pivotal in transforming agriculture since the Green Revolution. High Yielding Varieties (HYVs) of wheat and rice, increased use of chemical fertilizers, and expansion of irrigation significantly raised agricultural productivity (Evenson and Gollin, 2003). However, productivity is lower than the potential in large parts of the country. While modern technologies led to impressive yield improvements in irrigated areas, the productivity gains in rain-fed and dryland regions have been much lower.

The technology gap among regions and crops is one of the most pressing issues. Large technology gaps were observed in important areas of agriculture production where the adoption of new technology was slow and inadequate. For example, the realised yield levels were almost lower by 40-60 per cent compared to the potential yields of rice (Table 2).

TABLE 2. YIELD GAPS FOR IMPORTANT CROPS IN DIFFERENT STATES OF INDIA (kg/ha)

| State | Potential | Actual | Gap | Profit | Irrigated area (%) | Govt procurement (% of production) |
|---|---|---|---|---|---|---|
| | | | Rice | | | |
| Bihar | 5000-6500 | 2282 | 3468 (60.3) | 12924 | 71.23 | 0.0 |
| Punjab | 5000-6500 | 4366 | 1384 (31.7) | 83613 | 99.7 | 97.3 |
| West Bengal | 4400-6300 | 2996 | 2354 (44.0) | 5404 | 51.08 | 14.3 |
| Andhra Pradesh | 4400-6300 | 3765 | 1585 (29.6) | 33627 | 97.27 | 57.3 |
| Uttar Pradesh | 5800-6300 | 2733 | 3317 (54.8) | 2357 | 90.23 | 28.8 |
| Tamil Nadu | 6000-7000 | 3760 | 2740 (42.1) | 20792 | 93.40 | 23.2 |
| Chhattisgarh | 4800-6400 | 2101 | 3499 (62.5) | 39932 | 36.64 | 78.0 |
| Telangana | 6300 | 3693 | 2607 (41.3) | 34076 | 99.41 | 60.1 |
| | | | Wheat | | | |
| Punjab | 6470-7590 | 5003 | 2027 (28.8) | 61962 | 99.07 | 89.2 |
| Haryana | 6470-7590 | 4834 | 2196 (31.2) | 66402 | 99.69 | 81.3 |
| Uttar Pradesh | 6470-7590 | 3604 | 3426 (48.7) | 42981 | 98.61 | 16.6 |
| Rajasthan | 6470-7590 | 3676 | 3354 (47.7) | 53556 | 99.38 | 24.7 |
| Madhya Pradesh | 4500-6470 | 3449 | 2036 (37.1) | 47507 | 97.21 | 57.2 |
| Gujarat | 4500-6470 | 3262 | 2223 (40.5) | 42598 | 97.10 | 5.1 |
| Bihar | 6470 | 2780 | 2705 (49.3) | 30450 | 95.60 | 7.3 |

Note: Potential productivity was calculated by taking two important and recently recommended varieties for that region/state by the ICAR-National Institute of respective crops, and then the minimum and maximum yield of those two varieties was averaged out. The highest yield attained during any of the years from 2019-20 to 2021-22 was taken as the actual yield. Profit is calculated by subtracting A2+FL from the value of main and by-product for 2021-22.

The average rice productivity in Bihar and West Bengal was only about 23 q/ha and 30 q/ha, respectively, against the corresponding potential of 50-60 q/ha and 44-63 q/ha. On the other hand, productivity in Punjab was about 44 q/ha, constituting 60 per cent of the potential. The same was the story for the wheat crop. Punjab state harvests around 50 q/ha of wheat, whereas productivity is only 36 q/ha in UP, 34.5 q/ha in MP, 32.5 q/ha in Gujarat, and 27.8 q/ha in Bihar, which is about 71, 51, 63, 60 and 51 per cent of the potential, respectively. The potential yield in these states is 45-65 q/ha. Other studies also indicated similar results. Significant yield gaps (around 40 per cent) were observed for wheat and maize in Bihar and Uttar Pradesh (Ray *et al.*, 2012), 50 per cent for wheat in Madhya Pradesh (Jat and Gupta, 2010), 50 per cent for maize in Gujarat (Fischer and Byerlee, 2014), and 50 per cent for cotton in Gujarat (Dixit *et al.*, 2017).

The performance of pulses and oilseeds was even worse as these crops were grown on marginal lands. The average productivity of chickpea in its important growing states, such as Rajasthan, Maharashtra, Madhya Pradesh, Karnataka, and Jharkhand, was 8-14 q/ha against the potential of 20-25 q/ha, half the potential yields (Table 3). In the case of pigeon pea, the realised productivity was in the range of 10-13 q/ha in Uttar Pradesh, Madhya Pradesh, Jharkhand, Maharashtra, and Karnataka, while the potential exists up to 20-26 q/ha in these states. Important groundnut growing states were better placed and were harvesting more than 70-75 per cent of the potential yield. The realised productivity of groundnut was 22.5 q/ha in Rajasthan, 27.5 q/ha in Gujarat, and around 30 q/ha in Tamil Nādu. The yield gap in groundnut was estimated as 50-60 per cent in Andhra Pradesh (Kumar and Rao, 2001) and 30-50 per cent for chickpea and pigeon pea in Maharashtra and Madhya Pradesh (Kumar *et al.*, 2008). A vicious cycle of low productivity leading to low profits causing less than optimal use of inputs and constrained private investments for the improvement of land and enhancing irrigation capacities, which further leads to low yield, operates in states of Bihar, Uttar Pradesh, Madya Pradesh, Chhattisgarh, Jharkhand, Odisha, West Bengal, Rajasthan, etc. Further, limited irrigation availability leads to the cultivation of less-paying crops (pulses, oilseeds, and coarse cereals) in these areas.

This yield gap can be attributed to several factors, including inadequate access to high-quality seeds, less than optimum use of fertilizers, lack of irrigation, and lower mechanization. Supply of institutional credit in central states is much lower than in north-west and southern states. Therefore, farmers lack access and affordability to high-quality, high-yielding seeds, fertilizers, and pesticides, which limits their ability to achieve potential yields. Farmers often use traditional or locally available seed varieties that have lower productivity. For water, they largely depend on erratic monsoon rains. Farm mechanization is unevenly distributed. Punjab and Haryana's use of tractors and other machinery is widespread, whereas smallholders in other regions rely on traditional tools and manual labour. This uneven distribution of mechanization contributes to lower productivity in less mechanized states, as farm operations are slower and less precise.

TABLE 3. YIELD GAPS IN PULSES AND OILSEEDS IN DIFFERENT STATES OF INDIA

| State/Crop | Potential Yield (Kg/ha) | Actual Yield (Kg/ha) | Yield Gap (Kg/ha) | Yield Gap (% of potential) | Irrigated area (%) | Profits (Rs./ha) |
|---|---|---|---|---|---|---|
| | | | Chickpea | | | |
| Rajasthan | 2000-2500 | 1101 | 1149 | 50.0 | 45.9 | 28148 |
| Maharashtra | 1800-2000 | 1096 | 804 | 42.3 | 24.3 | 21218 |
| Madhya Pradesh | 2000-2200 | 1398 | 702 | 33.4 | 79 | 29701 |
| Karnataka | 1800-2000 | 782 | 1118 | 58.8 | 11.6 | 15084 |
| Jharkhand | 1500 | 1257 | 243 | 16.2 | 27.3 | -4846 |
| | | | Pigeon pea | | | |
| Uttar Pradesh | 2500-2600 | 1195 | 1355 | 53.1 | 14.3 | 39888 |
| Madhya Pradesh | 2100-2500 | 1305 | 995 | 43.3 | 2.2 | 30030 |
| Jharkhand | 2500-2800 | 1129 | 1521 | 57.4 | 2.2 | |
| Maharashtra | 2100-2500 | 1042 | 1258 | 54.7 | 1.6 | 46305 |
| Karnataka | 1700 | 759 | 941 | 55.4 | 12.4 | 10487 |
| | | | Groundnut | | | |
| Rajasthan | 2054-3154 | 2259 | 345 | 13.2 | 87.9 | 79442 |
| Maharashtra | 2013-2579 | 1318 | 978 | 42.6 | 20.8 | -10478 |
| Madhya Pradesh | 1631-2741 | 1791 | 395 | 18.1 | 6.8 | -9676 (2019-20) |
| Karnataka | 2013-2579 | 999 | 1297 | 56.5 | 26.2 | 17905 |

Note: Potential productivity was calculated by taking two important and recently recommended varieties for that region/state by the ICAR-National Institute of respective crops, and then the minimum and maximum yield of those two varieties was averaged out. The highest yield attained during any of the years from 2019-20 to 2021-22 was taken as the actual yield.

Climate variability in the form of frequent droughts and erratic rainfall further escalates water scarcity, adversely impacting crop productivity. For example, pulses are typically grown in rain-fed or water-scarce areas in central and western states, making them highly vulnerable to erratic rainfall. Pulses are susceptible to various pests and diseases, and significant yield losses occur due to their outbreaks, especially in regions with favourable conditions for their proliferation, such as Andhra Pradesh, Karnataka, etc. Limited market access affects the profitability and investment capacity of farmers. They are not covered by MSP policy and often receive lower prices than MSP. Only about 23 per cent of farmers are aware of MSP, and a minuscule of their output is sold at MSP. Due to insufficient agricultural extension services, farmers receive inadequate guidance on best practices and new technologies. This knowledge gap prevents the widespread adoption of innovations that could enhance yields.

### *2.7 Regional Income Disparities*

The skewed distribution of farm income among different states/regions is another key issue facing Indian agriculture. Farmers in states like Punjab, Haryana, and Tamil Nadu earn significantly more than their counterparts in states like Jharkhand, Odisha, and Bihar. The average income of agricultural households in Punjab was the highest at Rs 26701 per month (2018-19), approximately 3-4 times higher than that of farmers in Jharkhand, Chhattisgarh, Bihar, Odisha, Uttar Pradesh, Madhya Pradesh and Assam, highlighting the stark regional inequalities in farm income. Hoda and Rajkhowa (2016) also found that income in the western and northern regions was 50-60 per cent higher than in north-eastern states. Such disparities can be attributed to differences in productivity, access to irrigation and market, market infrastructure, and state-specific policies. While farmers in Punjab benefit from extensive irrigation systems and well-developed markets, those in Jharkhand and Bihar often struggle with poor infrastructure and poor access to institutional credit and markets. The states' relative positions over time also changed due to varying rates of agricultural growth, policy impacts, and diversification into non-farm activities. While Punjab and Haryana consistently demonstrated high income, Kerala, Maharashtra, Karnataka, and Andhra Pradesh improved their standing due to diversification towards high-value crops and non-farm activities. States that lagged consistently were Bihar, West Bengal, and Uttar Pradesh due to smaller landholdings, less mechanization, and weaker infrastructure.

## III

## ENVIRONMENTAL CHALLENGES AND SUSTAINABILITY OF AGRICULTURE

The environmental sustainability of Indian agriculture is under severe threat due to the overexploitation of natural resources and the widespread use of intensive farming practices. Decades of reliance on high-input farming methods, introduced during the Green Revolution, have yielded significant gains in agricultural productivity. However, these practices have led to long-term environmental degradation, with serious consequences for the sustainability of farming in India. In addition to the pressures of population growth and rising food demand, the impacts of climate change are further complicating efforts to ensure the long-term sustainability of the agricultural sector.

### *3.1 Water Scarcity and Groundwater Depletion*

Water scarcity is one of the most pressing environmental challenges facing Indian agriculture today. Agriculture accounts for approximately 80 per cent of the country’s freshwater consumption, and India is the world’s largest user of groundwater. Over-reliance on groundwater for irrigation has led to alarming levels of depletion. According to the Central Ground Water Board (CGWB), around 20 per cent of India's development blocks are overexploited, and another 14 per cent fall into the critical or semi-critical category of groundwater use. In Punjab, Haryana, Rajasthan, and Tamil Nadu, over 40 per cent of blocks face severe groundwater over-exploitation and depletion. The situation is particularly dire in the Green Revolution belt, where the cultivation of water-intensive crops like rice has led to the rapid depletion of aquifers. Free or heavily subsidized electricity to pump groundwater for irrigation has exacerbated the over-use of this valuable resource. In Punjab, groundwater levels are falling by nearly one meter per year, and if the current trend continues, the region could face severe water shortages soon. More than 85 per cent of its development blocks are over-exploited. The unsustainable use of groundwater has far-reaching implications for farmers and the environment. As water tables decline, farmers are forced to dig deeper wells, which increases their production costs and makes farming less economically viable. Moreover, the depletion of groundwater reserves threatens the long-term sustainability of agriculture, as future generations may not have access to the water resources needed to sustain crop production.

### *3.2 Soil Degradation and Loss of Soil Fertility*

Soil health is another concern. It is a critical factor in determining agricultural productivity, yet intensive farming practices have severely compromised it. The overuse of chemical fertilizers, particularly nitrogen-based fertilizers like urea, has disrupted the soil's nutrient balance, leading to soil degradation and reduced soil fertility. Monocropping wheat and rice in irrigated areas has further aggravated the problem, as these crops are typically grown in rotation without incorporating organic matter to replenish the soil. Excessive use of chemical fertilizers has also led to the leaching of nitrates into groundwater, contributing to the contamination of water sources. In addition, the heavy reliance on monocropping has reduced biodiversity in agricultural ecosystems, making crops more vulnerable to pests and diseases. Soil erosion, particularly in hilly and semi-arid regions, has contributed to the loss of topsoil, reducing the land's productivity and exacerbating the impacts of climate change on agriculture.

### *3.3 Air Pollution and Crop Residue Burning*

Stubble burning, particularly in the northern states of Punjab and Haryana, is another major environmental challenge associated with agriculture in the country. After harvesting paddy, farmers often burn the leftover straw to quickly clear fields for the next sowing season, releasing large amounts of particulate matter, carbon dioxide, and other greenhouse gases into the atmosphere. This practice contributes significantly to air pollution, particularly in the northern region, where air quality deteriorates sharply during the stubble-burning season in late autumn. The environmental and health impacts of stubble burning are severe. The release of fine particulate matter (PM2.5) into the air has been linked to respiratory illnesses and cardiovascular diseases, while the greenhouse gases released contribute to climate change. Despite government efforts to provide farmers with subsidies for stubble management machinery, such as happy seeders and straw balers, stubble burning continues due to the high cost and logistical challenges associated with alternative residue management methods.

*3.4 Climate Change and Its Impact*

Climate change is no longer a distant possibility but an imminent reality, and its impact on agriculture is profound and far-reaching. Indian agriculture, heavily dependent on the monsoon and vulnerable to climatic variability, faces serious threats from changing weather patterns, rising temperatures, and increased frequency of extreme weather events. The consequences of these changes are already being felt, particularly by small and marginal farmers whose livelihood hinges on agricultural production.

The average surface temperature in India has increased by about 0.6-1.0°C between 1901 and 2020. This rise has been more pronounced in the maximum temperatures, particularly during summer. Heatwaves have become more frequent and have particularly impacted northern and central India, where major heat events were recorded in 2003, 2015, and 2019. Heat stress significantly reduces the yields of heat-sensitive crops like wheat and rice by accelerating the evaporation of soil moisture, thereby requiring more irrigation and increasing farmers' vulnerability for their livelihood. While there has been only a marginal decline in total annual rainfall across India, its distribution has become increasingly erratic. The Indian monsoon, which accounts for 70-80% of the country's rainfall, has shown greater variability, with some regions receiving heavy downpours while others experience droughts during the same monsoon season. This variability disrupts the growing season and affects crop yields, particularly in rain-fed areas of central and western India. A shortened rainy period reduces the moisture available for crops like rice, which are highly dependent on extended monsoon periods.

The frequency of droughts has increased, particularly in semi-arid regions like Maharashtra, Rajasthan, and parts of southern India. In areas like Maharashtra's Vidarbha region, prolonged droughts have led to significant losses in crop production and have been linked to a rise in farmer suicides. Similarly, floods have become more intense, with states like Bihar, Assam, and Kerala facing frequent crop losses due to waterlogging and soil erosion. Droughts and floods directly impact agricultural productivity and farmer incomes, as extreme weather events often lead to crop failures. Financial consequences are devastating for smallholders, for whom each growing season matters. Many farmers are forced to rely on loans, which often exacerbate their financial difficulties in the long run.

Several studies have shown the negative impact of climate change on crop yields in India. A study by the Indian Agricultural Research Institute (IARI) estimated that wheat yields could decline by 6-23 per cent by 2050 due to rising temperatures. Similarly, rice yields could decrease by 2-8 per cent in most regions of India, with higher losses (up to 15-20 per cent) in eastern and southern parts of the country. The combination of higher temperatures and erratic rainfall patterns is particularly damaging for crops like wheat, rice, and maize, which are sensitive to climatic changes. In regions with low groundwater levels, higher demand for irrigation further increases water scarcity, leading to reduced yields and threatening long-term agricultural sustainability. Farmers gradually shift their crop patterns as temperatures rise and water becomes scarcer. In some areas, high water-consuming crops like rice are replaced by less water-intensive crops like millets and pulses. This shift is particularly notable in drought-prone regions like Maharashtra and Gujarat, where farmers increasingly turn to drought-resistant crops such as bajra (pearl millet) and sorghum. While these shifts may mitigate some of the impacts of climate change, they also present new challenges. Many farmers lack support to transition to new crops successfully, and the market for these crops may not be as well-developed as that for traditional staples like rice and wheat.

Warmer and wetter conditions have led to higher incidence of pests and diseases. For example, the fall armyworm, which affects maize crop, has spread rapidly across India since 2018, and diseases like leaf rust in wheat and blast in rice have become more common as changing weather patterns create conducive environments for their spread. Pest management and disease control practices increase the cost of production for farmers. The over-extraction of groundwater for irrigation, combined with erratic rainfall, has compounded the problem of emerging water scarcity in states like Punjab and Haryana and may render agriculture unsustainable in the near future.

## IV

## POLICY FRAMEWORKS, MARKETS, TECHNOLOGY AND PUBLIC INVESTMENTS

Agricultural policy frameworks in India have long been shaped by the need to balance food security with the economic welfare of farmers. Since independence, the Indian government has implemented a series of policy interventions aimed at enhancing/stabilizing farmer incomes, increasing productivity, and ensuring the availability of affordable food for the population. However, while these policies have succeeded in boosting agricultural output and food security, they have also led to unintended consequences, such as regional disparities, market inefficiencies, and environmental degradation.

This section explores key policy interventions in markets, technology, institutions, and infrastructure to improve economic efficiency and their environmental consequences and distributive efficiency.

### *4.1 Minimum Support Price (MSP) System: Ensuring Price Stability*

The MSP system has been one of the most important policy interventions in Indian agriculture since the mid-1960s. It was designed to protect farmers from price fluctuations and market volatility by guaranteeing a minimum price for their produce. Initially focused on key cereals like wheat and rice, the MSP was expanded to cover a broader range of crops, including pulses, oilseeds, and cotton. This intervention has been particularly effective in incentivizing food grain production, leading to India's emergence as a major global producer of wheat and rice.

While the MSP system has successfully stabilised prices and ensured a fair income for farmers, its benefits have been concentrated in specific regions and crops (Dev and Rao, 2010). Farmers in states like Punjab, Haryana, and western Uttar Pradesh, where government procurement is robust, have benefited the most from the MSP system, as they can reliably sell their wheat and rice to the government at guaranteed prices (Chand, 2003). In contrast, farmers in other parts of the country, particularly those growing crops not covered by public procurement, often receive prices below the announced MSP, exacerbating regional income disparities (Appendix 2). The over-reliance on the MSP system for wheat and rice has also contributed to monocropping and the cultivation of water-intensive crops in irrigated regions. This has led to environmental degradation, particularly groundwater depletion, as farmers in states like Punjab and Haryana prioritize rice production at the cost of the environment and natural resources.

*4.2 Input Subsidies: Balancing Productivity and Sustainability*

The Indian government has long provided subsidies on agricultural inputs such as fertilizers, electricity, irrigation, and credit to reduce production costs and improve productivity. These subsidies were instrumental in driving the success of the Green Revolution, as they enabled farmers to adopt modern farming techniques and increase food grain production. However, over time, input subsidies have led to inefficiencies and environmental degradation, particularly in the form of overuse of chemical fertilizers and unsustainable groundwater extraction.

One of the most significant input subsidies is on fertilizers, particularly nitrogen-based fertilizers like urea, which has led to the over-application of nitrogen, disrupting the nutrient balance in the soil and causing long-term soil degradation. The overuse of chemical fertilizers substituting farm yard manure and other organic matter enhancing farming practices like green manuring has reduced soil fertility, necessitating even higher fertilizer use in the future. Similarly, subsidy on electricity for groundwater extraction has led to the unsustainable over-exploitation of aquifers, particularly in states like Punjab, Haryana, Tamil Nadu, and Rajasthan (Gulati and Narayanan, 2002: Dev and Rao, 2010). Farmers in these states, encouraged by free or subsidized electricity, have extracted groundwater at unsustainable rates, leading to falling water tables and, consequently, higher investments in more powerful pumps, increasing production costs and further depleting groundwater resources.

*4.3 Public Investments in Agriculture*

Public institutions play a crucial role in the development of agriculture in developing countries like India, where farmers are small and marginal and cannot make investments on their own. The growth of agriculture in India largely depends upon the public investments made in developing markets, agricultural research and extension, value addition, storage, and irrigation. Major public investments occur in maintaining existing irrigation projects, markets, and storage (Gulati and Bathla, 2002). Further, excessive delays in completing such projects cause cost spillovers. As a result, there remains a relatively lower allocation for new irrigation projects, rural infrastructure, research and development, and processing capacities for agricultural commodities, mainly fruits and vegetables.

Agriculture subsidies are widely used worldwide, but their nature and magnitude vary. In India, non-specific input subsidies, such as fertilizer, power, surface water (canal water), and credit subsidies, are given in agriculture. Subsidies are provided in the initial stages of introducing new inputs, but their long-run continuation leads to sub-optimal and inefficient use of such inputs.

Indian agriculture has registered an increasing burden of agricultural input subsidies. Fertilizer subsidy increased by 10 times (from Rs 745 per ha in 2000-01 to Rs 8,285 per ha in 2023-24 at 2011-12 prices), power subsidy by more than 5 times (from Rs 1,454 per ha to Rs 8,990 per ha) and irrigation subsidy by about 1.5 times (from Rs 794 per ha to Rs 1,895 per ha). Put together, input subsidies went up from Rs 2,993 per ha to Rs 19,170 per ha, respectively, about 5.5 times during this period (NAAS, 2023). In gross value, input subsidies on fertilizers, power, and irrigation increased from Rs 55,462 crores in 2000-01 to Rs 4.05 lakh crores in 2023-24. An equally substantive increase was seen in the food subsidy bill, which rose from Rs 17,494 crore to Rs 2.11 lakh crore.

Small and marginal farmers, due to low income, are unable to afford inputs at market prices and need to be supported to sustain production for the food security of poor strata of our population and to remain in business. From that perspective, input costs must be subsidized to keep food prices low. Thus, the diversion of resources from investment to current expenditures in the form of subsidies is witnessed in Indian agriculture. Consequently, public investments are much lower than subsidies and constitute less than 3 per cent of the GVA of agriculture, whereas input subsidies eat up more than 7 per cent of the GVA (Table 4). It is being argued that agricultural subsidies are increasing rapidly and eating up the state's financial resources. Little is being left for public investments, curtailing the productive capacity of resources.

Public investment and subsidies have been empirically proven to reduce rural poverty and enhance growth. Still, opinions differ on which is more important, equitable, and sustainable. Subsidies encourage the use of those productive inputs, the benefits of which have not been widely demonstrated yet, whereas investments help increase the productive capacity of the farming unit.

TABLE 4. INPUT SUBSIDIES AND PUBLIC INVESTMENTS IN AGRICULTURE (Rs crores at 2011-12 prices)

| Year | Total (Input subsidies) | Food Subsidy | Public Investments | GVA | Input subsidies as % of GVA | Public investments as % of GVA |
|---|---|---|---|---|---|---|
| 2000-01 | 55,462 | 17,494 | 8,176 | 4,49,746 | 12.33 | 1.82 |
| 2005-06 | 40,884 | 23,071 | 20,739 | 6,39,988 | 6.39 | 3.24 |
| 2010-11 | 1,02,008 | 62,929 | 31,968 | 12,99,884 | 7.85 | 2.46 |
| 2015-16 | 1,82,745 | 1,34,900 | 56,167 | 22,27,533 | 8.20 | 2.52 |
| 2020-21 | 2,51,045 | 2,82,770 | 1,00,775@ | 33,68,471 | 7.45 | 2.99 |
| 2023-24 | 4,05,157 | 2,11,394 | Na | 52,51,104 | 7.72 | Na |

Note: @ was computed by assuming the average of the proportions of public investments out of total investments for the years 2016-17, 2017-18 and 2018-19.
Sources: Agricultural Statistics at a Glance, 2022 and NAAS, 2023.

However, the distribution of input subsidies is inequitable and tilted more towards medium, large, and influential farmers, widening the gap between rich and poor farmers (Gulati and Sharma, 1995). For example, there is more use of fertilizers in Punjab; therefore, a large share of subsidies per unit area goes to it. Further, fertilizer use is higher in paddy and wheat crops, thus more subsidies. The same is the story in power subsidy. Large farmers own more electric motors, accessing a higher share of subsidies. Estimates show that 56 per cent of farm power subsidy goes to farmers owning more than 4 ha of land in Punjab. Paddy is a water-intensive crop that accounts for a bigger share (about 75%) of power subsidies. Regarding credit subsidy, southern states and northwest Gangetic plains have more access to institutional credit than their share as per crop acreage. Central and eastern states of India have much lower accessibility to cheap agricultural credit from institutional sources. On the other hand, the distributive efficiency of public investments in agriculture is considered relatively more equitable among farm classes, and its returns are higher than input subsidies (Fan *et al.*, 2008).

*4.4 Agricultural Research and Extension*

The role of agriculture research and development in raising productivity and income through technology development, innovations, and their dissemination and adoption in farmers' fields is well documented. Every rupee spent on agriculture research pays off Rs 13.85, and on extension, Rs 7.40 (Kandpal *et al.*, 2024). As a norm, the expenditure on research and development in agriculture should constitute around 2 per cent of its GDP. However, due to the limited availability of such large resources, research expenditure remained at less than one per cent in India. Kandpal *et al.* (2024) estimated the average agriculture research expenditure to be 0.61 per cent of agriculture GDP and of agriculture extension 0.16 per cent from 2011 to 2020. In 2008-09, research expenditure was as high as 0.75 per cent of agriculture GDP, which, however, was reduced to about 0.45 per cent in 2022-23 due to the growing magnitude of agricultural inputs and food subsidies and currently the direct income transfer of Rs 6000 per annum to the bank accounts of small and marginal farmers.

Agriculture research expenditure is incurred through ICAR, the apex agricultural research body of the country, and State Agricultural Universities. ICAR is funded by GOI, and SAUs are primarily funded by state governments, although these also receive some funds from ICAR. Besides low investment in agriculture research, another point of concern is allocating these resources among different sub-sectors of agriculture such as crop husbandry, horticulture, animal sciences, natural resources management, agriculture extension, etc. In nominal terms, the ICAR expenditure increased from Rs 1900 crore in 2005-06 to Rs 5995 crore in 2016-17 and Rs 8513 crore in 2022-23. However, at 2011-12 constant prices, it increased from Rs 2923 crore to Rs 4874 crore and further to Rs 5098 crore correspondingly, with an average annual increase of 4.4 per cent. However, the budgetary allocation to ICAR decreased from 0.25 per cent of GVA in agriculture in 2005-06 to 0.17 per cent in 2022-23.

Sub-sector-wise allocation was available only up to 2016-17, as shown in Figure 1. Field crops, a major contributor to GVA, received the largest allocation, followed by animal sciences. From 2000-01 onwards, natural resources came under threat due to intensive cultivation in some regions of the country and thus received the fourth largest allocation. KVKs expanded significantly during this period for strengthening agricultural extension services and received the third largest allocation, which was substantially pegged up in 2016-17. During this period, the horticulture sector also emerged as one of the main drivers of agricultural growth, and its allocation almost doubled in 2016-17 compared to 2005-06.

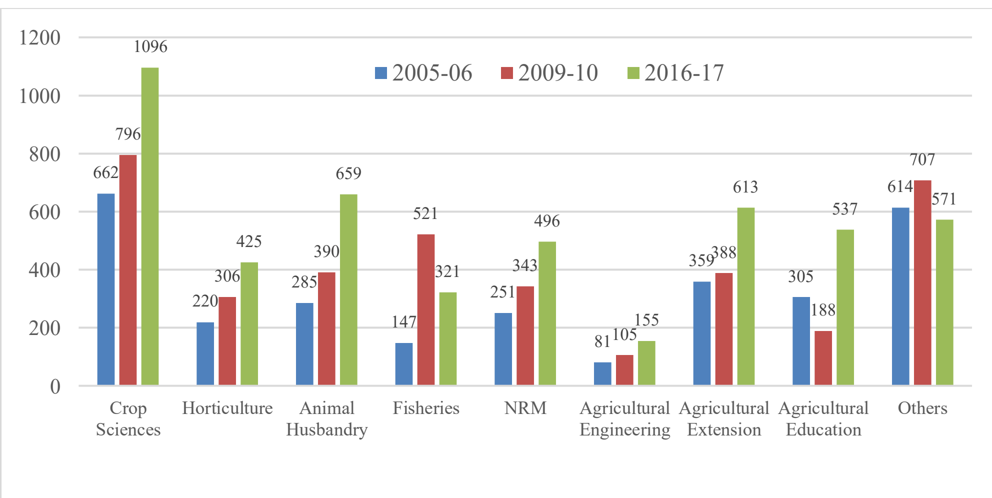


Figure 1. ICAR Outlay under different Sub-sectors (Rs. Crore at 2011-12 prices)
Source: Annual Reports of ICAR, various issues.

Proportional allocations to different sub-sectors show that the share of crops declined from 22.6 per cent in 2005-06 to 20.9 per cent in 2016-17, and that of animal husbandry increased from 9.7 per cent to 12.6 per cent, respectively, keeping in view the growing importance of animal husbandry in the growth of agriculture sector. There was a marginal increase in the share of horticulture from 7.5 per cent to 8.1 per cent. Though the shares of agricultural extension and agriculture education declined marginally during this period, agriculture extension received the third largest attention in allocation.

There are some lessons to learn from the distribution of these outlays. Extension services come mainly in the domain of states through their departments of agriculture and thus should be left to them. ICAR should focus on core, strategic, and basic research to provide a lead in cutting-edge technology development and innovations. The budgetary allocations to ICAR do not fully meet the growing needs for research and development in agriculture. With increasing challenges in agriculture, such as climate change, pest resistance, and the need for sustainable practices, the proportional reductions in areas like crop science and natural resource management may hinder long-term growth and innovation in the sector. The allocations indicate a preference for maintaining overall funding levels despite the growing demands of various agricultural sub-sectors. A more strategic allocation that addresses these pressing needs could better support the sector's future growth.

In relative terms, animal husbandry and horticulture research under ICAR received significant attention, reflecting the sector's importance in contributing to nutritional security, income diversification, and export potential. However, their allocation has not seen substantial increases. In horticulture, modest funding levels may not fully address the challenges such as pest management, post-harvest losses, and varietal improvement to meet global market standards. Additionally, research into climate-resilient varieties is crucial as the sector is highly vulnerable to climate change. While the current allocation reflects the balance between research and extension, a significant increase in research funding is warranted to keep pace with the growing challenges in agriculture, ensuring a futuristic approach to both short-term and long-term agricultural growth with sustainability.

## V

## TECHNOLOGICAL INTERVENTIONS AND INNOVATION

The role of technology in Indian agriculture has evolved significantly over the past several decades. However, the contribution of technology to growth has reduced from 38.9 per cent during 1980-81 to 1999-2000 to 28.6 per cent during 2000-01 to 2021-22, and that of prices has increased from 27.9 per cent to 43.8 per cent during this period (Chand *et al.*, 2023). This has necessitated a new wave of technological innovations, considering that technology is a better option for growth with greater distributive gains than prices. These innovations range from biotechnology and precision agriculture to digital tools such as mobile applications and the Internet of Things (IoT), all of which help farmers increase productivity, manage resources efficiently, and access better markets. In the face of climate change, resource scarcity, and the growing demand for food, adopting advanced technologies is critical for ensuring the sustainability and economic viability of Indian agriculture. This requires the adoption of a two-pronged strategy. In those states where productivity is currently low, yield-enhancing technologies such as high-yielding seeds, fertilizers, and irrigation must be promoted. Since farmers' income in these states is low, the availability of subsidized institutional credit has to be improved. They will also be required to be protected from climate shocks through PMFBY. Secondly, for all the regions of the country, new technologies have to be employed for sustainable growth and income enhancement, such as application of biotechnology tools for varietal development, precision agriculture for resource use efficiency, and digital methods for providing weather, market and other production-protection related information to farmers.

### *5.1 Biotechnology: Enhancing Crop Yields and Resilience*

Biotechnology has the potential to revolutionize agriculture by addressing many of the key challenges facing the sector, including pest infestations, drought, and low crop yields. For instance, the introduction of Bt cotton, a genetically modified crop resistant to the bollworm pest, has transformed cotton production in India. Bt cotton has helped farmers reduce their reliance on chemical pesticides, lowering input costs and mitigating environmental pollution. Moreover, biotechnology has the potential to enhance the nutritional quality of crops through the development of biofortified varieties rich in essential vitamins and minerals, contributing to improved food security and public health. The adoption of biotechnological innovations such as Bt cotton in India, biofortified pearl millet in Maharashtra, Rajasthan, and Uttar Pradesh, drought tolerant rice varieties in eastern India, and tissue culture in banana cultivation in Maharashtra and Tamil Nadu exemplifies the significant of biotechnology to enhancing agricultural productivity, promoting sustainability, and improving nutritional security.

However, the adoption of GM crops in India has been limited to Bt cotton, as the commercial cultivation of genetically modified food crops, such as GM mustard, has faced regulatory hurdles and public opposition. Concerns about the safety of GM crops, their impact on biodiversity, and the control of seeds by multinational corporations have contributed to a cautious approach to biotechnology in India. Moving forward, biotechnology can play a critical role in addressing the impacts of climate change by developing climate-resilient crops that are tolerant to drought, heat, and salinity through Marker Assisted Selection technique of gene transfer for desirable traits, which is being used widely in the national agricultural research system. These crops will be essential for sustaining agricultural productivity in regions increasingly affected by erratic weather patterns and water scarcity.

*5.2 Precision Agriculture: Optimizing Resource Use*

Precision agriculture uses technology to optimize the application of inputs, such as water, fertilizers, and pesticides, based on real-time data. This approach enables farmers to apply inputs in precise amounts, reducing wastage and maximizing productivity. Precision agriculture technologies, such as soil sensors, GPS-guided tractors, and remote sensing, allow farmers to monitor the health of their crops and make informed decisions about when and how to apply inputs. One of India's most widely adopted precision agriculture technologies is drip irrigation, which delivers water directly to the roots of plants, reducing evaporation and water wastage. This method has been particularly effective in water-scarce regions, where farmers struggle with declining groundwater levels. Drip irrigation conserves water and improves crop yields by ensuring plants receive consistent moisture.

Similarly, using real-time data, sensor-based technologies can monitor plant health, soil fertility, and soil moisture levels, allowing farmers to apply fertilizers and water more efficiently. In addition, drones are increasingly used in Indian agriculture to survey fields, detect pest infestations, and monitor crop growth. By providing aerial imagery and data, drones help farmers identify problems early and take corrective actions before they escalate.

Despite the potential of precision agriculture to improve productivity and resource efficiency, the adoption of these technologies in India has been slow, particularly among smallholders. The high cost of precision agriculture equipment, such as GPS-guided machinery and drones, is a significant barrier for small and marginal farmers, who often lack the financial resources to invest in advanced technologies. Lack of access to institutional credit further limits their ability to adopt precision farming practices.

*5.3 The Internet of Things (IoT) and Digital Tools*

The Internet of Things (IoT) and digital tools transform Indian agriculture by providing farmers with real-time data on weather conditions, soil moisture, crop health, and market prices. IoT-based devices, such as smart sensors and automated irrigation systems, allow farmers to monitor and manage their fields remotely, reducing the need for manual labour and improving resource use. In addition to IoT devices, mobile applications have become powerful tools for empowering farmers with information and market access. Apps like Kisan Suvidha, IFFCO Kisan, and AgriMarket provide farmers with real-time updates on weather forecasts, pest advisories, and government schemes. These apps also offer information on market prices, enabling farmers to make better decisions about when and where to sell their produce.

*5.4 The Role of Drones in Agriculture*

Drones are emerging as a game-changer in Indian agriculture, offering farmers a cost-effective way to monitor large fields and manage crop health. With highresolution cameras and sensors, drones can capture detailed images of fields, allowing farmers to detect signs of pest infestations, nutrient deficiencies, or water stress early in the growing season. This information enables farmers to take timely corrective actions, reducing crop losses and improving yields. In addition to monitoring crops, drones can also be used for precision application of pesticides and fertilizers, ensuring that inputs are applied only where needed. This reduces the overuse of chemical inputs, lowers production costs, and minimizes environmental pollution. Several states, including Karnataka and Maharashtra, have begun pilot programs to introduce drones in agriculture, providing subsidies and training to farmers on effectively using these technologies.

While drones offer significant potential for improving agricultural productivity, their adoption is still early. High costs, regulatory restrictions, and lack of training for farmers have limited their widespread use in agriculture. However, with the government's focus on promoting Agri-Tech innovations, there is significant potential for drones to become a mainstream tool in the agricultural sector.

Despite numerous benefits of technological interventions in agriculture, several barriers still hinder their adoption, particularly among smallholders. High upfront costs of precision agriculture equipment, IoT devices, and drones make it difficult for small farmers to invest in these technologies. Additionally, lack of access to institutional credit and financing options limits their ability to adopt advanced farming practices.

## VI

## CHANGING CONSUMPTION PATTERN AND THE ROLE OF HORTICULTURE, VALUE ADDITION AND ORGANIC FARMING

Markets have changed during the last two decades and thrown open new opportunities for growth. The domestic demand for horticultural commodities is rising due to changes in the consumption pattern, which signals farmers to adjust production choices. The proportional per capita monthly expenditure on fruits and vegetables increased in 2022-23 compared to 2004-05, whereas that on cereals declined. It went up from 7.34 per cent of total consumption expenditure to 9.09 per cent in rural areas and from 5.92 per cent to 17.10 per cent, respectively, in urban India (NSO, 2024). Similarly, the corresponding increase for processed products and beverages increased from 4.38 per cent to 9.62 per cent in rural areas and from 5.91 per cent to 10.64 per cent in urban areas. The increase was relatively greater in processed products than in fresh fruits and vegetables. The expenditure on cereals declined from 17.45 per cent to 4.91 per cent during this period in rural India and from 9.63 per cent to 3.64 per cent in urban India. This is happening due to increase in per capita income, lifestyle changes, greater consciousness towards nutrition, etc. Responding to increased demand, horticulture has emerged as a significant growth driver in Indian agriculture, contributing to income diversification, improved nutrition, and employment generation (Chand and Saxena, 2014; Chand and Singh, 2023). Horticulture offers farmers a profitable alternative to traditional crops such as wheat and rice. By focusing on high-value horticultural crops and investing in value addition through processing and marketing, Indian farmers can achieve greater income stability and market resilience. This sector has consistently registered higher growth than the crop sector, almost double the rate of the crop sector since 2000. The CAGR of horticulture was estimated at 4.0 per cent against 2.4 per cent in the crop sector during 2000-10 and 4.7 per cent against 2.2 per cent during 2010-22.

*6.1 Horticulture as a Key Growth Driver*

India is the second-largest producer of fruits and vegetables globally. The area under horticulture crops has increased from 16.6 million hectares in 2000-01 to over 25 million hectares by 2021-22. Production has also surged from 145.8 million tonnes to about 331 million tonnes during this period, driven by significant improvements in productivity and diversification. Adopting improved varieties, advanced irrigation techniques (e.g., drip and sprinkler systems), protected cultivation practices, and better pest and disease management have contributed to the growth of this sector. Various government schemes, such as the Mission for Integrated Development of Horticulture (MIDH), Rashtriya Krishi Vikas Yojana (RKVY), and the National Horticulture Mission, have played a crucial role in promoting horticulture by focusing on improving infrastructure, post-harvest management, and providing financial assistance to farmers.

Horticulture offers higher value per hectare compared to traditional cereals. The average value productivity of fruits (on 2011-12 prices) at Rs 2,61,221 per ha in 2022-23 was 5.5 to 6.0 times and that of vegetables at Rs 1,94,449 per ha 4.5 to 5.0 times of wheat and paddy. Further, horticultural crops are more profitable than field crops. Chand *et al.* (2015) reported that horticultural crops gave 27 per cent higher income than the households cultivating cereals. Similarly, it was estimated that farmers cultivating fruits and vegetables received 30-40 per cent higher income compared to those growing staple crops (Gandhi and Koshy, 2006), and those engaged in horticulture and food processing received 35-50 per cent higher income than those relying solely on traditional field crops (Singh and Rangi, 2019).

*6.2 Value Addition and Agri-processing*

Value addition involves processing raw agricultural products into higher-value goods, such as processed foods, beverages, and biofuels. The food processing sector in India accounts for about 32 per cent of the total food market. Reducing post-harvest losses, improving perishable commodities' shelf life, and enhancing agricultural products' marketability is critical. A relatively small proportion of agricultural produce undergoes value addition in India. In horticulture, for example, only 7 per cent of fruits and vegetables are processed, compared to much higher levels in developed countries. This represents a significant untapped potential for value addition, which can help increase farmers' incomes and reduce food wastage. Value addition in agriculture can benefit farmers in realising better prices by improving market access (in the form of value-added products with better shelf life), bringing price stability (negotiating prices with processors, reducing losses through processing), and access to modern technology and production practices.

The Pradhan Mantri Kisan Sampada Yojana (PMKSY) and the Mega Food Park Scheme have focused on building food processing infrastructure, including cold storage facilities, agro-processing clusters, and food testing labs. Operation Greens was launched in 2018 to stabilize the supply of tomato, onion, and potato (TOP) crops and to ensure their availability throughout the country at affordable prices. Initiatives included the creation of value chain infrastructure, setting up production clusters, and providing transportation and storage facilities. National Mission on Food Processing (NMFP) was launched to promote facilities for post-harvest operations, including the setting up of food processing industries. These programs aim to reduce post-harvest losses and improve farmers' access to markets, enabling them to capture more value from their produce.

While the food processing industry in India has made significant progress, there is still a need for more inclusive growth to ensure that small and marginal farmers across all regions can benefit from these advancements (Jha *et al.*, 2015). Factors that hinder value addition include infrastructure constraints, limited access to capital, poor technology adoption, lack of direct access to the market, and regulatory barriers. Cold storage facilities are inadequate, produce moves in unrefrigerated vehicles, and small and marginal farmers often face difficulties accessing credit for investing in processing equipment and technologies. Traditional and inefficient processing practices lead to lower productivity and quality. Farmers and small processors lack the skills and knowledge to implement advanced processing techniques. By addressing these barriers and implementing targeted strategies, India can significantly enhance the level of value addition in its field and horticulture crops, leading to higher incomes for producers and improved food security and quality for consumers.

Processing units and food processing companies may facilitate technology transfer to farmers, providing training and guidance on advanced production practices, processing techniques, and quality control measures. Farmer Producer Organizations (FPOs) and cooperatives can play a role in aggregating produce and accessing shared processing facilities and technology.

### *6.3 Organic Farming*

As consumers increasingly demand healthier, more sustainable food options, organic farming has gained attraction as an alternative to conventional agriculture. Organic farming emphasizes using natural inputs such as compost, manure, and biological pest control methods, avoiding synthetic chemicals and fertilizers. This approach not only improves soil health but also reduces environmental pollution and enhances the long-term sustainability of farming systems.

Organic farming is practiced across various states in India, such as Sikkim, Uttarakhand, Madhya Pradesh, Rajasthan, and the north-eastern states. Sikkim became India's first fully organic state in 2016, with 75,000 hectares of agricultural land under organic cultivation. The state government banned chemical fertilizers and pesticides and encouraged farmers to switch to organic practices. This transition was supported through government subsidies, training programs, and organic certification processes. Today, Sikkim is known for its organic production of crops like ginger, turmeric, and cardamom, boosting the state's agricultural productivity and tourism. Madhya Pradesh is one of India's largest producers of organic food, with vast areas under organic cultivation, mainly focusing on crops like wheat, pulses, and soybean. Rajasthan is also known for the organic production of spices, oilseeds, and cereals, especially in arid regions.

The Timbaktu Collective in Andhra Pradesh is another success story of organic farming. This collective has been instrumental in promoting organic farming in the drought-prone Anantapur district of Andhra Pradesh by transforming over 3200 ha into organic-certified farms and has also empowered small farmers for organic farming. Farmers cultivating groundnut, millets, and pulses have seen reduced input costs and improved yields.

The Indian government has launched several schemes to promote organic farming, such as Paramparagat Krishi Vikas Yojana (PKVY), focusing on cluster-based organic farming, providing financial assistance to farmers; Mission Organic Value Chain Development (MOVCD-NER) in the North-East focusing on value chain development and marketing, and National Program for Organic Production (NPOP) which facilitates certification and promotion of organic products, ensuring adherence to organic standards.

The demand for organic products in India is rapidly increasing, driven by growing health consciousness, awareness of environmental issues, and the rising purchasing power of consumers. The Indian organic food market was valued at around Rs 2,000 crore in 2021 and is expected to grow at a CAGR of over 20 per cent from 2022 to 2027. Organic exports from India crossed US$1 billion in 2020-21, with products like rice, oilseeds, and tea being major contributors. The key markets for Indian organic exports include the USA, EU, and Canada. This increasing demand is translating into larger areas being brought under organic cultivation. India now has 2.78 million hectares of farmland certified for organic farming, making it one of the largest organic food producers globally.

An empirical study by ICAR has revealed that organic farms, while sometimes yielding 10-20 per cent lower in early years, tend to match or even surpass conventional yields after a few years due to improved soil health and fertility. Organic farming increases profitability due to lower input costs by 20-40 per cent with premium prices of up to 20-30 per cent higher, improving profit margins over conventional farming. Organic farming also brings environmental benefits through composting, crop rotation, and green manuring, enhancing soil organic carbon levels by 0.3–0.6 per cent per year, increasing biodiversity, and reducing water usage compared to conventional farms.

Despite the benefits, some significant constraints and challenges hinder the growth of organic farming in India, such as yield loss in the initial year (10-25 per cent), lengthy and costly certification process, and poor market access. Market linkages for organic produce are still weak. According to a report by FICCI, 80 per cent of India's organic produce is sold in unorganized markets as organized retail chains for organic products are lacking, which limits consumer access. The lack of proper storage facilities and cold chains for organic produce exacerbates post-harvest losses, which can be as high as 30-40 per cent for perishable organic produce like fruits and vegetables. Government interventions, alongside public-private partnerships, are needed to provide technical training, reduce certification barriers, and establish organized markets to boost the organic farming sector's growth and sustainability.

## VII

## REFORMS FOR ADVANCING AGRICULTURAL GROWTH WITH SUSTAINABILITY

The agricultural sector in India is at a critical juncture. The current policy framework that once drove productivity and food security has created unintended consequences, such as regional imbalances, resource depletion, and market distortions, and must now evolve to meet such challenges, including environmental sustainability, market integration, and the economic well-being of farmers. Comprehensive reforms are essential to align agricultural policies with the emerging realities of markets, resources, climate, global food system demands, etc., to ensure the long-term growth and sustainability of agriculture. These reforms, which are discussed below, must address economic and environmental challenges while promoting technological innovations, market efficiency, public investments, crop diversification, and inclusivity for small and marginal farmers.

### *7.1 Technology Upgradation and Sustainable Farming Practices*

Many regions in the country have not yet fully benefitted from technological advancements. The technology gap, particularly in central and eastern regions, is large and multifaceted, involving both systemic and localized issues, whereas technological advancements and innovations are considered prime engines for equitable and sustainable growth. It is, therefore, crucial to promote region-specific technologies that can enhance productivity in these underperforming areas. Improved seeds, irrigation network, and chemical fertilizers need to be encouraged in these areas by creating awareness, building a strong input distribution network, and making institutional credit available at low interest rates.

Emphasis on developing and disseminating cutting-edge agricultural technologies suited to local conditions can significantly enhance productivity and income in such regions. Biotechnology tools need to be used extensively and intensively for the varietal development of desirable traits to address the problems of low productivity, pest resistance, climate resilience, etc. Precision agriculture has also become very important in promoting the use of inputs in optimal quantities as per the needs of the plant and helping avoid wastage. These technologies and practices carry great potential in ensuring the efficient application of water and nutrients through sensors. Micro irrigation systems such as drip and sprinkler are examples of precision agriculture, which have become popular and are thriving in the protected cultivation of vegetables and orchards. Laser land leveller is another highly successful sensor-based technology that has been widely used in the state of Punjab. It has exhibited its usefulness as an enabling technology for efficient water use. Such technologies can turn around agriculture in water-scarce regions of the country.

The application of drones is also being pushed in agriculture, considering their usefulness in identifying pest infestations and their community-based control/eradication. Similarly, smart agriculture technologies such as IoT and data analytics can help optimise input use and improve decision-making. Providing subsidies and training for these technologies can facilitate their adoption.

Access to quality inputs must be improved by ensuring the availability and affordability of high-quality seeds, fertilizers, and pesticides through better distribution networks and subsidies, especially for small and marginal farmers. Cooperative institutions network can be used for this purpose. Punjab state has successfully made fertilizer and other inputs available through cooperative societies.

Establishing systems for monitoring pest and disease outbreaks and providing early warnings can help farmers take timely preventive measures. Promoting natural predators and biopesticides can reduce dependency on chemical pesticides. Encouraging IPM practices that combine biological, cultural, and mechanical methods for pest control can reduce reliance on chemical pesticides. Governments and institutions should promote eco-friendly alternatives to chemical inputs, which are less harmful to the environment.

Soil health restoration can improve soil health and biodiversity by encouraging organic farming practices, including compost, green manure, and bio-fertilizers. Conservation agriculture techniques like no-till farming, in-situ crop residue management, cover cropping, and crop rotation can help preserve soil structure, increase organic matter, and reduce erosion. Promoting soil health cards and site-specific nutrient management can optimize fertilizer use and reduce its overuse.

### *7.2 Promoting Sustainable Water Management*

Water scarcity is one of the most pressing challenges facing Indian agriculture. Over-extraction of groundwater for irrigation, particularly in states like Punjab, Haryana, Tamil Nadu, and Rajasthan, has led to alarming levels of depletion. Promoting sustainable water management practices is essential to address this challenge. One of the key strategies is adopting micro-irrigation systems, such as drip and sprinkler irrigation, which deliver water directly to the plant roots, reducing evaporation losses and ensuring more efficient water use. Sub-surface irrigation is also a significant method for efficient water use and is considered helpful in sugarcane, cotton, orchards, etc. Government programs like the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) have promoted micro-irrigation in the country. Still, adopting these technologies needs to be scaled up, particularly in water-scarce regions.

In addition, the government should encourage crop diversification away from water-intensive crops, such as rice and sugarcane, particularly in regions facing severe water shortages. Providing financial incentives and support to farmers to switch to less water-intensive crops, such as pulses, oilseeds, and millets, can help conserve water while maintaining farm incomes. Public awareness campaigns on the benefits of crop diversification and water conservation will be crucial in encouraging farmers to adopt these changes.

### *7.3 Strengthening Agricultural Market Reforms*

The fragmentation and inefficiency of agricultural markets in India remain significant barriers to improving farmers' income and reducing post-harvest losses. Many farmers, mainly smallholders, depend on local markets, often at the mercy of middlemen and receiving prices far below the MSP. Inadequate infrastructure, such as storage facilities and transportation networks, exacerbates these challenges, leading to high post-harvest losses and low price realization for farmers.

The government should invest in developing post-harvest infrastructure, including cold storage facilities, warehouses, and transportation networks, to reduce post-harvest losses and improve the quality of agricultural produce, followed by strengthening market linkages through innovative marketing methods, which help farmers get better prices for their produce by connecting them directly with buyers. The National Agriculture Market (e-NAM) platform was a critical step toward integrating fragmented agricultural markets in the country and providing farmers access to a larger, more competitive marketplace. However, the adoption of e-NAM has been slow, and many farmers still lack the digital literacy and resources needed to fully benefit from this platform. Expanding e-NAM to more mandis and improving digital literacy among farmers is crucial to making e-NAM more effective. Therefore, the government needs to invest in digital infrastructure, improve connectivity in rural areas, and train farmers to use the platform effectively.

Strengthening market intelligence systems, effectively implementing and utilising price stabilization funds for certain horticultural crops, and developing efficient supply chain management to stabilize prices can help mitigate market risks. Integrating these initiatives with improvement in rural infrastructure, including roads, storage, and logistics, will help enhance the profitability and sustainability of farming.

Farmer Producer Organizations (FPOs) can play a key role in facilitating market access for smallholders, enabling them to aggregate their produce, negotiate better prices, and access shared infrastructure, such as storage, transportation, and machinery services. Farmers can reduce transaction costs, increase their bargaining power, and access new markets more effectively by acting collectively. Strengthening FPOs through government support and capacity-building programs is essential for improving market efficiency and increasing farmers' income. Successful models of FPOs need to be identified and replicated. For example, in Karnataka, HOPCOMS supplies inputs to farmers at reasonable prices and collects the horticultural produce directly from them.

*7.4 Reforming Minimum Support Price (MSP) System*

The Minimum Support Price (MSP) system has played a crucial role in stabilizing prices for farmers and ensuring food security by incentivizing the production of staple crops like wheat and rice. However, the system has also contributed to monocropping and overproduction of water-intensive crops, particularly in states like Punjab and Haryana, resulting in the depletion of groundwater resources, soil degradation, and an imbalance in crop patterns. Promoting crop diversification and ensuring sustainable agricultural practices are therefore essential. One potential reform could involve broadening the scope of MSP to include a wider variety of crops, particularly those that are more sustainable and less water-intensive, such as pulses, oilseeds, and coarse cereals. Their remunerative MSP and assured marketing would incentivize farmers to diversify their cropping patterns and reduce pressure on groundwater and soil fertility. It will also be helpful in augmenting farm incomes in low-productivity regions by assuring them MSP. Assured and remunerative prices are also pivotal for promoting the adoption of new technologies and investments to raise productivity.

MSP may be ensured by not allowing FHP to be less than MSP through market intervention or other methods. The consumer may bear the burden of higher prices of agricultural produce if it happens due to the implementation of MSP. Poor consumers can be protected by subsidies, as is currently being done.

Another option is to move toward a system of price deficiency payments, where farmers are compensated for the difference between the market price and the MSP without requiring the government to procure the crops. This would reduce the fiscal burden on the government while still providing farmers with a guaranteed minimum income.

Alternatively, DBT-like programs can also be designed to support the farmers to wean them away from MSP and input subsidies regime to encourage market forces to decide resource allocation and crop choices considering the changing dynamics of markets if all the stakeholders agree to such a mechanism.

### *7.5 Reforming Input Subsidies for Sustainability*

Input subsidy reforms are needed to encourage more efficient use of resources. Such reforms are also essential for promoting sustainable agricultural practices. One potential reform is to reduce subsidies on nitrogen-based fertilizers and increase subsidies on potassium and phosphorus, which are currently under-applied. This would help restore nutrient balance in the soil and improve long-term soil health. Additionally, promoting organic fertilizers and encouraging integrated nutrient management (INM) practices can reduce the reliance on chemical inputs and enhance soil fertility.

Similarly, electricity subsidies for extracting groundwater should be replaced with targeted subsidies for water-efficient technologies, such as drip irrigation and solar-powered pumps. By promoting renewable energy for irrigation, the government can reduce water and energy consumption in agriculture. These measures can help ensure the sustainable use of groundwater resources and reduce the environmental impact of agriculture.

Targeting input subsidies has become necessary because these are inequitable. Thus, these need to be rationalized and restructured in favour of small and marginal farmers, who need this the most.

Small farmers still lag in using optimum levels of yield-enhancing inputs and need support to reduce the technology gap. Direct income support in place of input subsidies can help bridge this technology gap. Enhanced access to institutional credit to small farmers and in disadvantaged regions can be helpful while reducing input subsidies to sustain/obtain optimal use of resources.

To further incentivize sustainable farming practices, the government can introduce payments for ecosystem services, where farmers are compensated for adopting practices that conserve natural resources, reduce greenhouse gas emissions, and improve biodiversity. These payments can be tied to measurable outcomes, such as reduced water usage, improved soil health, or lower carbon emissions (Kumara, *et al.*, 2024)

### *7.6 Enhancing Research and Development (R&D) and Extension Services*

Considering the contribution of agriculture to GDP, employment, and income, investments primarily in irrigation, markets, storage, and research need to be enhanced to accelerate its growth with equity and sustainability. Agricultural research, education, and rural roads are the three most effective public spending items in promoting agricultural growth and poverty reduction (Fan *et al.*, 2008).

Increased public investments in agriculture research to at least 1% of agriculture GDP is pivotal for driving innovations and addressing region-specific challenges, particularly in climate change and resource scarcity. This will help develop new cultivars, technologies, and farming practices to improve productivity, climate resilience, and sustainability. Research needs to be focused more on biotechnology, precision farming, climate resilience, horticultural crops, mechanisation for small farmers, and developing new scalable value-added products. Large financial allocation to ICAR and SAUs is critical to meet the technological challenges facing agriculture. Greater funding in agricultural research is also warranted because research in biotechnology, precision farming, and digital technologies is capital-intensive. Private-sector investment in agricultural research must be ensured through incentives such as tax breaks, grants, and public-private partnerships. It can be crucial in bringing cutting-edge technologies to the agricultural sector.

Agricultural extension services must also be strengthened to improve farmers' access to the latest innovations and farming techniques. Extension services should promote climate-resilient farming practices such as drought-resistant crop varieties, integrated pest management, precision farming, and conservation agriculture. These services should also disseminate knowledge about market trends, price forecasts, and new market opportunities. Greater use of digital tools should be employed to reach the last mile. Such tools help provide timely information on scheduling various farm operations, market information, weather information, and availability of inputs and services. States should largely shoulder this responsibility.

In addition to government-led extension services, private-sector involvement in agricultural extension has been growing. Companies offering digital platforms, such as agri-tech startups, provide farmers with real-time data on weather, soil health, and market prices, enabling them to make informed decisions. Collaborations between the government, private sector, and research institutions can help bridge the gap between technology and smallholder farmers, ensuring that innovations reach even the most remote regions.

By providing farmers with timely and accurate information, extension services can help improve productivity, reduce input costs, realise better prices of the produce, and enhance environmental sustainability.

*7.7 Promoting Climate-resilient Agriculture*

Climate change is a growing threat to Indian agriculture, affecting crop yields and farmer livelihoods. To mitigate its impacts, it is necessary to promote climate-resilient agriculture, which includes using drought-resistant and heat-tolerant crop varieties and climate-smart practices. The role of agricultural biotechnology is central in the development of such cultivars. Agroforestry, which integrates trees into agricultural landscapes, is another promising approach to building resilience to climate change. Conservation agriculture, which includes minimum tillage, crop rotation, and cover crops, can also help farmers adapt to climate variability while improving soil health and reducing greenhouse gas emissions.

The government should invest in climate-smart infrastructure, such as weather forecasting systems, early warning systems for floods and droughts, and insurance schemes that protect farmers from the financial risks associated with climate variability. These investments will help farmers better prepare for and respond to climate-related challenges, reducing the agricultural sector's vulnerability to climate change. Offering incentives for adopting climate-smart practices and technologies can encourage their widespread adoption. Specific insurance products suitable to local needs at low premiums must be designed to meet the financial risks of climate variability at a micro level.

### *7.8 Encouraging Horticulture and Value Addition*

Crop diversification is crucial for improving farm incomes and reducing the risks associated with market fluctuations or climate shocks. Farmers should be encouraged to move beyond traditional staples like wheat and rice and explore higher-value crops like fruits, vegetables, and medicinal plants. Horticulture was found to be an important source for accelerating growth in agriculture (Birthal *et al.*, 2008). However, diversification needs to be supported by expanding access to markets for these crops and providing incentives for farmers to invest in their value addition. The development of modern markets backed up by post-harvest infrastructure is pivotal for accelerating growth in agriculture.

Another key strategy for enhancing farmers' incomes and improving the profitability of Indian agriculture is to promote value addition and agri-processing for which significant potential exists. Agri-processing clusters, cold chain infrastructure, and food processing units can help reduce post-harvest losses, improve quality, and create new market opportunities for farmers. Economic incentives and leveraging participation of private investments/corporate sector in agro-processing and value addition are necessary to promote agricultural growth, employment, and farm incomes in the country.

Government programs such as the Pradhan Mantri Kisan Sampada Yojana (PMKSY) and the Mission for Integrated Development of Horticulture (MIDH) are already promoting value addition and processing in the agriculture sector. However, more must be done to ensure that smallholders, who often lack access to processing infrastructure, can benefit from these opportunities. Focus on food processing by leveraging the One District One Product model can be a turning point in encouraging food processing in the country.

*7.9 Some other Policy Measures*

Allied activities like dairy farming, poultry, beekeeping, and aquaculture can supplement farmers' incomes. These activities can be integrated into existing farming systems for better resource utilization and reducing dependency on crop production alone (NITI Aayog, 2017).

Greater access to institutional credit in central and eastern states needs to be ensured for optimal use of various inputs and modern farming practices, as well as private investments in developing irrigation facilities, land improvement, and suitable farm machinery for timeliness and precision farming. The coverage of small and marginal farmers by institutional credit needs improvement through simplified loan processes, reducing collateral requirements, and enhancing their share in the total portfolio for agriculture. Microfinance institutions and self-help groups can also play a vital role in this direction. Specific credit facilities need to be designed for horticulture, with lower interest rates and flexible repayment schedules, which can improve investment in the sector.

Expanding and enhancing crop insurance schemes like PMFBY can provide financial protection against crop failures due to climate extremes. Innovative insurance products must be designed per regional requirements depending on resource endowment, crop pattern, nature and extent of climate variability, and the economic position of farmers.

Robust monitoring and evaluation frameworks must be created to assess the impact of government policies and programmes by regularly reviewing and adjusting policies based on feedback and outcomes to ensure continuous improvement. Farmer feedback into the research and policy development process must be interwoven to enhance effectiveness and relevance. Further, the policy stance should be inclusive and address the needs of smallholders. Those technologies and practices are developed and promoted to be affordable, accessible, and scalable for small-scale farming operations.

The Government of India has launched several initiatives to promote sustainable agriculture, such as the National Mission for Sustainable Agriculture (NMSA), focusing on promoting climate-resilient and resource-efficient farming practices, Pradhan Mantri Krishi Sinchai Yojana (PMKSY) aiming to improve irrigation efficiency and water conservation through micro-irrigation, Soil Health Card Scheme providing farmers with information on soil quality and recommendations for balanced fertilizer use, Paramparagat Krishi Vikas Yojana (PKVY) promoting organic farming practices and eco-friendly agriculture, Pradhan Mantri Fasal Bima Yojana (PMFBY) providing crop insurance against natural calamities and weather risks etc. These programmes help farmers attain sustainable use of resources, enhance productivity and farm income, along with coping climate uncertainty. Such programmes need to be strengthened and expanded to reap large-scale dividends.

## VIII

## THE FUTURE OF INDIAN AGRICULTURE: INTEGRATION OF TECHNOLOGY, MARKET AND SUSTAINABILITY

Indian agriculture stands at crossroads, facing significant challenges and immense opportunities. While the sector has achieved remarkable growth over the past six decades, it now faces pressing issues related to economic sustainability, environmental degradation, and climate change. Comprehensive reforms focusing on technological innovation, market efficiency, water resource management, and sustainable farming practices are needed to address these challenges.

India can accelerate agricultural growth while ensuring long-term sustainability by adopting a holistic approach that integrates technology, market, infrastructure, and policy reforms. Promoting climate-resilient agriculture, diversification, precision agriculture, digital tools, and biotechnology can increase productivity while reducing the environmental footprints of farming. Developing modern markets with post-harvest infrastructure, scientific storage, and value addition, improving access to markets by linking producers with consumers, and providing real-time information on prices, farming practices, and weather, along with technological interventions, will help build a more efficient, inclusive and resilient agricultural sector that benefits both farmers and consumers. At the same time, policies that promote sustainable farming practices, such as organic farming and agroforestry, will be critical for addressing the environmental challenges associated with modern agriculture. The government's focus on supporting Farmer Producer Organizations (FPOs) and investing in rural infrastructure will help ensure that smallholders are not left behind in transitioning to a more modern and sustainable agricultural system. In the years ahead, India's ability to balance economic growth with environmental stewardship will be vital to ensure food security, improve rural livelihoods, and sustain the agricultural sector for future generations.

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APPENDIX 1. AREA UNDER HIGH-YIELDING VARIETIES, FERTILIZER USE AND IRRIGATED AREA IN INDIA

| | 1965-66 | 2021-22 |
|---|---|---|
| Area under HYVs (million ha) | | |
| Wheat | 1.89 | 31 |
| Rice | 1.28 | 44 |
| Pulses | 0.2 | 12 |
| Production (million tons) | | |
| Wheat | 10.4 | 107.74 |
| Rice | 45.89 | 193.24 |
| Pulses | 9.94 | 27.3 |
| Fertiliser use (million tons) | 0.5 | 66.8 |
| Irrigated area (million ha) | 24 | 72 |

APPENDIX 2. FARM HARVEST PRICES OF DIFFERENT CROPS, 2022-23 (Rs/q)

| Crop/State | MSP | FHP | Districts covered (No) | Districts where FHP<MSP (No) | Range of FHP when FHP<MSP | FHP<MSP (as % of MSP) |
|---|---|---|---|---|---|---|
| Paddy | 2060/2040 | | | | | |
| Uttar Pradesh | | 1919 | 18 | 13 | 1570-2014 | 1.27-23.0 |
| Odisha | | 1554 | | | | |
| Andhra Pradesh (Kharif) | | 1993 | 13 | 9 | 1820-2030 | 0.5-10.8 |
| Andhra Pradesh (Rabi) | | 2002 | 12 | 8 | 1686-2016 | 1.17-17.3 |
| Andhra Pradesh (All season) | | 1996 | 13 | 10 | 1821-2036 | 0.19-10.8 |
| Bihar (Afghani) | | 1673 | 38 | 38 | 1306-2008 | 1.6-36.0 |
| Bihar (Bhedea) | | 1538 | 22 | 22 | 1400-1840 | 9.8-31.4 |
| Punjab | | 2060 | 22 | 0 | - | Nil |
| Tamil Nadu | | 1995 | 30 | 14 | 1607-2034 | 0.3-21.2 |
| Telangana (Kharif) | | 1977 | 29 | 29 | 1932-2037 | 1.12-6.21 |
| Telangana (Rabi) | | 1939 | 29 | 29 | 1915-1969 | 3.5-6.1 |
| WHEAT | 2125 | | | | | |
| UP | | 2044 | 37 | 24 | 1700-2106 | 0.9-20.0 |
| MP | | 22O7 | 31 | 11 | 1800-2114 | 0.5-15.3 |
| Rajasthan | | 2262 | 32 | 3 | 2063-2117 | 0.4-2.9 |
| Punjab | | 2125 | 22 | 0 | - | |
| Bihar | | 2086 | 38 | 20 | 1619-2118 | 0.3-23.8 |
| Odisha | | 2076 | 10 | 6 | 1400-2074 | 2.4-34.1 |

Source: Farm harvest prices of principal crops in India, 2022-23, Agricultural Marketing Division, Ministry of Agriculture and Farmer Welfare, GOI, 2024