Sustainable Development In INDIA Moving Towards SDGs

EDITED BY

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ISBN: 978-93-7310-975-6

Cover design: Yash Singhal
Typesetting: Namrata Saini

First Edition: October 2025

PREFACE

Sustainable development is a major priority for India as it strives to balance economic growth with social development and environmental protection. The Sustainable Development Goals (SDGs) provide a clear framework to address long-standing challenges while making use of the country's diversity, traditions and new opportunities. They point the way toward inclusive progress, improved well-being and a stronger future for all.

This book, "Sustainable Development in India Moving Towards SDGs", brings together valuable insights from scholars across many fields, highlighting both achievements and challenges. The chapters cover a wide range of topics from all goals. Each chapter helps us understand the progress made and what still needs to be done to meet the targets by 2030.

This volume covers a broad range of important themes related to sustainable development in India, including economic growth, social development, environmental protection, climate action, agricultural sustainability, green finance, educational equity, health and well-being, skill development, energy policy, waste management and socio-political frameworks. Together, the editor's contribution as an author of the chapter provides a comprehensive view of India's progress towards all the Sustainable Development Goals.

What makes this book special is that it brings together ideas from economics, geography, education, life sciences, agriculture, history and political studies. By combining these perspectives, it shows how all these goals are connected and why working together is so important to reaching them. It is hoped that this book will serve as a useful resource for scholars, policymakers and students as well as anyone interested in India's development journey towards SDGs. By engaging with the ideas and evidence presented here, readers will gain a deeper appreciation of the opportunities and challenges that lie ahead on India's journey to achieving the SDGs by 2030. I sincerely thank all the contributors for their hard work, commitment and dedication in creating this volume and making its publication possible. I also appreciate the support from Vinoba Bhave University which has provided a great environment for research and teamwork.

Dr. Umendra Singh
Editor

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SUSTAINABLE DEVELOPMENT IN INDIA: ASSESSING THE OVERVIEW OF THE PROGRESS FROM VISION TO ACTION TOWARDS AGENDA 2030

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Abstract

India's effort toward the United Nations Sustainable Development Goals (SDGs) from 2015 to 2024 shows big progress as well as serious challenges. This study uses data analysis and policy review to look at all 17 goals. Poverty has gone down a lot with multidimensional poverty falling from 29.17% in 2013–14 to 11.28% in 2022–23 which means 248 million people moved out of deprivation. Access to clean water grew fast as tap water coverage went from 17% to 76% between 2015 and 2023 while renewable energy capacity rose from 39 GW to 220 GW. Still problems remain. Malnutrition continues under SDG 2 gender inequality under SDG 5 and climate action under SDG 13 is slow and uneven with big gaps across states. India's SDG index score improved from 58 in 2018 to 71 in 2023–24 but reaching the 2030 targets will need faster action better financing and stronger institutions. The study shows that India's SDG path gives useful lessons for other developing nations where real success depends on bringing together political will resources and community effort to achieve fair and lasting growth.

Keywords: Sustainable Development Goals, Governance, Inequality, Policy and Agenda 2030

Introduction

India is really going all-in on the Sustainable Development Goals or SDGs This is one of the biggest global efforts to build a better future as the world's most populated nation and one of the fastest growing big economies, what India does here matter a lot (NITI Aayog, 2024). The main driver of this push is NITI Aayog It acts as the lead coach, keeping an eye on progress and sharing updates every year through the SDG India Index (PIB, 2024) This index checks how India is doing on 113 targets that match the global SDGs while also tackling what matters most at home Since 2015. India has kept moving forward even when things got tough from the COVID-19 pandemic to economic ups and downs and climate disasters the overall SDG score climbed from 57 in 2018 to 71 in 2023–24 showing solid gains in lots of areas (United Nations in India, 2024). What makes India's approach stand out is the way the central government, states and local communities all pitch in Each level has its part to play States and union territories tweak the goals to fit their own needs and roll out projects that work for their areas This mix of national vision and local action is what's driving real change across the country (NITI Aayog, 2020)

Objectives of the Study

This study takes a close look at how India has moved toward the Sustainable Development Goals from 2015 to 2024 and digs into how different states and union territories are doing across these targets. It also checks out how big policy moves and flagship programs have helped push India's SDG efforts forward and shares what works and what still needs work on the road to sustainable development.

Research Methodology

This study adopts a mixed-methods design to evaluate India's SDG progress from 2015 to 2024 by combining quantitative trend analysis and qualitative policy review. Drawing on NITI Aayog SDG India Index reports, MoSPI statistics, sectoral ministry data and UN, World Bank and IMF indicators, the quantitative component uses 2015–16 as a baseline to conduct trend analysis and regional disparities. Concurrently the qualitative component undertakes a systematic policy review, institutional evaluation and analysis of coordination mechanisms to understand governance dynamics.

Review of Literature

Research on India's SDG journey has changed a lot since 2015. Early studies looked at how the SDGs fit with India's big development goals (Singh et al. 2022). Lately people have started digging into specific sectors, checking which policies work best and spotting gaps between regions.One reviews of papers says more than 12 percent of India's research covers SDG topics. Most of that work talks about good health and well-being (SDG 3), clean energy (SDG 7) and climate action (SDG 13) (Singh et al. 2022). But there is less focus on gender equality (SDG 5) and life below water (SDG 14). That shows where new research could really help when it comes to the big ideas guiding this work you see a few main approaches. Systems thinking facilitates the integration of various goals (Bennich et al. 2020). Institutional analysis checks how rules and accountability shape results (Emerald 2024). Competitive federalism looks at how states compare themselves using the SDG India Index (NITI Aayog 2024); and the capabilities approach focuses on human development in health, education and social protection (Mishra et al. 2023). These concepts collectively provide a more comprehensive understanding of the formulation and implementation of policies.Digging into specific areas, it has been noticed that real wins on poverty reduction social safety nets like the JAM trinity and direct cash transfers have helped a lot (UNDP India 2023). Health reforms through Ayushman Bharat have reached more people and helped moms and kids but non-communicable diseases are still a big challenge for India (PIB 2024). More schools are available for children now, yet learning gaps still exist. In gender studies it has been found there are more women in politics and better sex ratios, but economic and social inequalities still stick around (PIB 2024). When we look at the environment, India is leading in solar power and saving forests, yet water quality, air pollution and adapting to climate change remain tough issues (WEF 2022). All this work provides us a real feel for India's SDG path and points to where policies need to focus next.

PROGRESS OF SUSTAINABLE DEVELOPMENT IN INDIA

The progress of sustainable development in India can be analyzed by evaluating the progress of 17 Sustainable Development Goals (SDGs), which has been examined in the following sections:

SDG 1: No Poverty - Transforming Lives through Comprehensive Social Protection

India has achieved significant progress in alleviating multidimensional poverty with the rate has fallen from 2013-14 to 2022-23, pulling about 248 million people out of poverty (PIB, 2024) with the help of consistent economic growth, social safety programmes and focused policies addressing different issues i.e., including health, education and living conditions. The National Multidimensional Poverty Index (MPI) assists policymakers in understanding poverty across states, districts and demographic groupings (United Nations Development Programme [UNDP] India, 2023). The Pradhan Mantri Garib Kalyan Anna Yojana and the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) have played critical roles in ensuring food security and creating rural jobs. From 2015-16 to 2019-21, the poverty rate has fallen each year indicating that these measures were effective (MPPN, 2023); Uttar Pradesh, Bihar, Madhya Pradesh and Rajasthan have made good progress, although certain northeastern states continue to face challenges.

Table: 1 Trends in Multidimensional Poverty & Poverty Areas wise Poverty in India

Year	Multidimensional Poverty Rate (%)	Number of Poor (Millions)	Rural Poverty (%)	Urban Poverty (%)	Annual Decline Rate (%)
2005-06	55.34	645	59.2	39.4	-
2013-14	29.17	370	32.6	8.7	7.69
2015-16	24.85	315	27.9	8.6	8.12
2019-21	14.96	195	19.3	5.3	10.66
2022-23	11.28	148	14.7	4.2	9.24

Source: Ministry of Information and Broadcasting (PIB), 2024

The data in Table 1 shows that multidimensional poverty in India dropped from 55.34% in 2005-06 to 11.28% in 2022-23. This is because living conditions, healthcare and education have all gotten a lot better. The number of people living in poverty fell from 645 million to 148 million. Rural poverty is still higher than urban poverty but it is falling faster because of successful rural development programs. After 2013–14, poverty went down faster because of social support programmes and changes in the economy.

SDG 2: Zero Hunger - Securing Nutritional Outcomes for All

India's plan for zero hunger wants to make sure everyone has enough food, improve health through better nutrition and help farmers use sustainable methods. The National Food Security Act helps more than 800 million people by making sure food is shared widely. Stunting has decreased and wasting has gone down. This progress is due to programmes like PM POSHAN Abhiyan which provides meals to over 120 million children (India Today 2025). The ICDS scheme gives health checkups and nutrition education to more than 100 million children and mothers through 1.4 million anganwadi centers with recent improvements in quality (PIB 2024). India can produce enough food grains on its own with record harvests showing that agriculture is doing well (PIB 2024). The government supports farming that can handle climate change, save water and keep soil healthy.

Table 2: Trends in Key Child Nutrition Indicators in India (in %)

Indicator	2015-16	2017-18	2019-21	2022-23	Target 2030
Stunting	38.4	37.2	35.5	33.8	25.0
Wasting	21.0	20.1	19.3	18.7	15.0
Underweight	35.8	34.5	32.1	30.2	25.0
Anemia (children)	58.6	56.8	67.1	64.3	40.0

Source: Ministry of Information and Broadcasting (PIB), 2024; India Today, 2025

Table 2 shows that important child nutrition indicators in India have been getting better in recent years. The rate of stunting decreased from 38.4% in 2015-16 to 33.8% in 2022-23 shows improved child growth and less long-term undernutrition. Wasting and being underweight also went down steadily shows better short-term nutrition and overall health for children. Anemia in children is still a big problem with rates going up from 56.8% in 2017-18 to 64.3% in 2022-23. This shows that there are still issues with getting enough vitamins and minerals and we need to take focused steps to address this. Progress is good, but it needs to get faster to reach the 2030 SDG nutrition goals, especially for reducing anemia.

SDG 3: Good Health and Well-being - Building Resilient Health Systems

India's health sector changes have brought significant improvements in important health measures helping the country get closer to reaching SDG 3 goals. The number of mothers who died during childbirth went down from 2014-16 to 2019-21 which is a 28% decrease (PIB 2025). The number of babies who die before their first birthday went down from 2014 to 2021. Ayushman Bharat started in 2018 and was an important move towards universal health coverage, insurance to more than 500 million people (PIB 2024) and pays for hospital costs up to ₹5 lakh for each family every year. More than 300 million people have received help and over 50 million hospital admissions were supported. The number of medical colleges grew from 387 in 2014 to 658 in 2024 which helps to solve the shortage of healthcare workers (PIB 2024). The Digital Health Mission wants to build a connected digital health system to improve data sharing and care coordination. India's vaccination programme has given out more than 2.2 billion doses showing its strong ability to deliver (PIB 2024).

Table: 3 Trends in Key Health Indicators India with Global SDG Targets

Indicator	2014	2016	2018	2020	2022	2024	Global Target
MMR (per 100,000)	130	122	113	97	90	85	70
IMR (per 1,000)	39	34	32	28	26	25	25
NMR (per 1,000)	26	24	22	20	18	17	12
Life Expectancy (years)	68.3	68.8	69.4	69.7	70.2	70.8	75

Source: PIB-2025; Registrar General of India, 2025& World Health Organization, 2025

The table shows that India has made good progress in health measures over the last ten years because of government actions and economic growth. The number of mothers who die during childbirth dropped from 130 out of every 100,000 live births in 2014 to 85 in 2024 getting close to the global goal of 70. This is due to maternity benefits programmes those have improved maternal health facilities and have increased hospital births. The infant mortality rate went down from 39 to 25 for every 1,000 live births and the neonatal mortality rate decreased from 26 to 17 for every 1,000. People are living longer with life expectancy with going up from 68.3 years in 2014 to 70.8 years in 2024.

SDG 4: Quality Education - Universalizing Access and Improving Learning Outcomes

India has made good progress in achieving SDG 4: Quality Education with more students enrolling and staying in school at all levels. The Gross Enrollment Ratio (GER) in higher education increased from 2015-16 to 2022-

23 (Gitnux 2025) and literacy went up from 74.0% to 77.7% with women and marginalized groups. The Right to Education Act (2009) made it possible for almost everyone to enroll in primary school that reached over 96% (MoSPI, 2024). The Samagra Shiksha scheme helps education from pre-primary to class 12. Digital education grew quickly during COVID-19. Platforms like DIKSHA helped over 50 million students and 5 million teachers. PM eVIDYA used TV, radio and online ways to continue learning (PIB, 2024). More girls are going to school than boys in primary and upper primary levels.

Table: 4 Trends in Gross Enrollment Ratios and Gender Parity in Education in India

Education Level	Indicator	2015-16	2017-18	2019-20	2021-22	2023-24
Primary	GER (%)	99.2	101.4	103.0	104.8	105.2
	Gender Parity Index	1.02	1.04	1.05	1.06	1.07
Secondary	GER (%)	79.3	81.2	83.5	85.8	87.2
	Gender Parity Index	0.93	0.95	0.97	0.99	1.01
Higher Education	GER (%)	24.5	25.8	27.1	27.8	28.4
	Female GER (%)	24.2	26.4	27.3	28.1	29.2

Source: Ministry of Education, Government of India (2025)

Table 4 shows how India has been improving in enrollment and gender equality in primary, secondary and higher education from 2015 to 2024. The primary level Gross Enrollment Ratio was over 100%, showing that almost everyone has access to school. The percentage of secondary GER increased from 79.3% to 87.2% and the Gender Parity Index went up from 0.93 to 1.01 helping to close and slightly reverse the gender gaps, benefiting girls. Programs such as Beti Bachao Beti Padhao and scholarships have helped more girls advance to higher grades. In higher education, the gross enrollment ratio (GER) went up from 24.5% to 28.4%. The increase for females was even larger, rising from 24.2% to 29.2%.

SDG: 5 Gender Equality - Accelerating Women's Empowerment across All Spheres

India has made significant progress in achieving the gender equality in several important areas. The number of boys born for every 1,000 girls increased from 2015-16 to 2022-23 (PIB, 2024) and more women started working. The Women's Reservation Act (2023) requires that 33% of seats in Parliament and state assemblies be reserved for women. Economic empowerment grew with programmes like Mudra Yojana which helped more than 40 crore women entrepreneurs (Business Today, 2024). The Stand-Up India scheme helps women and marginalized groups start their own businesses while Mahila Shakti Kendra improves women's skills and job chances. One Stop Centres offer combined help with 733 centers across the country and the Women Helpline (181) is available 24/7 for support. The Nirbhaya Fund helps projects that aim to make women safer and more secure (PIB, 2024).

Table: 5 Trends in Gender Equality Indicators in India with Targets By 2030

Indicator	2015-16	2017-18	2019-21	2022-23	2024-25	Target
Sex Ratio at Birth	919	925	929	930	931	950
Female LFPR (%)	23.7	24.8	30.0	32.8	37.0	50.0
Women in Parliament (%)	12.0	12.5	14.2	13.6	14.1	33.0
Women in Managerial Positions (%)	15.2	16.8	18.5	20.2	22.1	30.0

Source: Ministry of Women and Child Development & Ministry of Labour and Employment, Govt. of India (2025).

Table 5 highlights both India's progress and the challenges it still faces in achieving gender equality by 2030, it shows that the number of boys born for every 1,000 girls rose from 919 in 2015–16 to 931 in 2024–25. The proportion of women in the workforce increased significantly from 23.7% to 37%. The shortfall from the 50% goal demonstrates the need for additional formal jobs and workplace support, such as childcare and maternity benefits while women are still underrepresented in decision-making roles. Participation in Parliament has gone up a little from 12% to 14.1% but this is still far from the goal of 33%. The number of women in management increased from 15.2% to 22.1% but they still fall short of the target of 30%.

SDG 6: Clean Water and Sanitation - Transforming Lives through Universal Access

India has performed excellent work in improving water and sanitation in the last few years and toilet coverage has also grown (Jal Shakti Ministry, 2024). The Jal Jeevan Mission has connected more than 15 crore homes with the help of community involvement, women leaders and sustainable water sources (DD News, 2023). The Swachh Bharat Mission supports this achievement by building more than 10.76 crore toilets since 2014 and reaching almost complete toilet coverage in rural areas (Swachh Bharat Mission, 2024). The Jal Jeevan Mission addresses this by requiring water testing and community monitoring, using technology like treatment plants and surveillance systems to make sure the water supply is safe (UNOPS, 2024).

Table: 6 Trends in Rural and Urban Sanitation and Drinking Water Coverage in India

Indicator	2015-16	2017-18	2019-20	2021-22	2023-24	Rural/Urban Coverage
Tap Water Coverage (%)	17.0	25.0	35.0	55.6	76.0	Rural: 76%, Urban: 85%
Toilet Coverage (%)	38.7	68.0	92.0	97.0	98.0	Rural: 98%, Urban: 99%
Open Defecation Free Villages	0	2.5L	5.5L	6.0L	6.02L	100% of villages
Water Quality Compliance (%)	45.0	52.0	62.0	72.0	81.0	Rural: 78%, Urban: 89%

Source: Ministry of Jal Shakti & Ministry of Housing and Urban Affairs, Government of India (2025)

Table 6 illustrates the advancements made by India in ensuring access to safe drinking water and sanitation from 2015 to 2024; during this timeframe the percentage of individuals with access to tap water has risen from 17% to 76% overall. In rural areas 76% of households have tap water while in urban areas it has reported 85%. The number of toilets increased a lot going from 38.7% to 98%. In rural areas, it reached 98% and in urban areas, it was 99%. By 2023–24, more than 602,000 villages were declared free of open defecation marking an important achievement in rural sanitation and hygiene. Water quality compliance went up from 45% to 81%; in rural areas compliance is at 78%, while in urban areas, it is at 89%.

SDG 7: Affordable and Clean Energy - Accelerating the Renewable Energy Transition

India's renewable energy sector has seen impressive growth with installed capacity has increased from 2015 to 2024. Solar power and wind energy has also grown (Press Information Bureau [PIB], 2025). This fast growth shows India's strong dedication to moving towards clean energy and its aim to achieve 500 GW of renewable capacity by 2030. Energy access has improved better with 99.9% of villages now having electricity (PIB, 2024). The PM Ujjwala Yojana gave LPG connections to over 10 crore homes cutting down on traditional biomass use and enhancing indoor air quality. Programmes such as the National Solar Mission and wind energy policies have encouraged private investment and innovation in this area (Ministry of New and Renewable Energy [MNRE], 2025). Green hydrogen is becoming very important with the National Green Hydrogen Mission aiming for 5 million tonnes each year by 2030. By distributing more than 38 crore LED bulbs, it helps lower electricity use and costs which supports India's larger goals for sustainable energy (Drishti IAS, 2025).

Table: 7 Trends in Renewable Energy Capacity and Rural Electrification in India

Energy Source	2015	2017	2019	2021	2023	2024	2030 Target
Total RE Capacity (GW)	39	57	82	110	180	220	500
Solar Capacity (GW)	4	12	32	48	75	105	280
Wind Capacity (GW)	27	32	37	40	48	52	140
Hydropower (GW)	45	46	47	47	48	49	65
Rural Electrification (%)	95.0	97.5	99.5	99.9	100.0	100.0	100.0

Source: Ministry of New and Renewable Energy & Central Electricity Authority, Govt. of India

Table 7 illustrates the swift growth of renewable energy capacity in India and the achievement of nearly universal rural electrification between 2015 and 2024. The total renewable capacity increased significantly from 39 GW to 220 GW, moving closer to the 2030 goal of 500 GW. The expansion of solar power has been remarkable, rising from 4 GW to 105 GW fueled by reductions in panel cost, the establishment of large solar parks and the implementation of decentralized solar initiatives such as PM-KUSUM. The increase in wind capacity was gradual and has increased from 27 GW to 52 GW that contributed to energy diversification. Hydropower recorded a modest increase from 45 GW to 49 GW.

SDG 8: Decent Work and Economic Growth - Building an Inclusive and Sustainable Economy

India's economic performance has remained robust amid global uncertainties with GDP growth averaging over 7% in recent years. The economy rebounded strongly from the COVID-19 pandemic, demonstrating notable resilience and adaptability (Economic Times, 2024). As the world's fifth-largest economy, India is poised to become the third-largest by 2030 fueled by strong domestic consumption, investment and structural reforms. Particular attention is being given to the informal sector which employs over 90% of India's workforce to promote formalization and extend social protection. The e-Shram portal has registered over 29 crore informal workers that offers them access to social security benefits and skill development programmes (Press Information Bureau [PIB], 2024).

Table: 8 Trends in Key Economic Indicators of India

Economic Indicator	2015-16	2017-18	2019-20	2021-22	2023-24
GDP Growth Rate (%)	7.4	7.0	4.2	8.9	8.2
Employment Growth Rate (%)	3.0	3.2	1.8	3.2	6.0
Unemployment Rate (%)	5.0	4.8	4.8	6.4	4.1
FLFPR (%)	23.7	24.8	26.0	30.0	37.0
Per Capita Income (₹)	86,647	1,05,000	1,26,406	1,50,326	1,97,000

Source: Ministry of Finance & Ministry of Labour and Employment, Government of India

Table 8 highlights the dynamic shifts in India's economic performance over the past decade. GDP growth maintained strong momentum until 2017–18 but slowed significantly to 4.2 percent in 2019–20 due to domestic slowdown and global uncertainties. The sharp rebound to 8.9 percent in 2021–22 reflected post-pandemic recovery and expansionary policy support. Growth stabilized at 8.2 percent in 2023–24. Employment growth showed a fluctuating pattern. It fell to 1.8 percent in 2019–20 reflecting structural job market challenges but recovered to 6.0 percent in 2023–24 driven by expansion in services, manufacturing and digital economy sectors. Unemployment rates remained stable at around 5 percent until 2019–20 but spiked to 6.4 percent during the pandemic. The fall to 4.1 percent in 2023–24 underscores improved labour market absorption though quality of employment remains a concern.A notable trend is the steady rise in female labour force participation. FLFPR grew from 23.7 percent in 2015–16 to 37.0 percent in 2023–24. Per capita income almost doubled from ₹86,647 in 2015–16 to nearly ₹2, 00,000 in 2023–24.

SDG 9: Industry, Innovation and Infrastructure - Building the Foundation for Sustainable Development

India's infrastructure development has accelerated markedly in recent years with capital expenditure rising from ₹7.7 trillion in 2019 to ₹12.2 trillion in 2023 (Press Information Bureau [PIB], 2024). In digital infrastructure, transformative gains have been made with internet users and broadband connections have increased over the years (PIB, 2024). The BharatNet project has successfully connected over 2.18 lakh gram panchayats with high-speed internet. Transportation infrastructure has seen major improvements, boosting connectivity and lowering logistics cost. The total road network has grown with focused development of high-quality highways and rural roads enhancing accessibility (PIB, 2024). The Startup India initiative has recognized over 1 lakh startups, fostering a vibrant entrepreneurial culture and the number of patents filed have nearly doubled from 43,000 in 2015 to over 85,000 in 2024 (PIB, 2024).

Table: 9 Trends in Infrastructure Development in India

Infrastructure Sector	2015-16	2017-18	2019-20	2021-22	2023-24	Investment (₹ Lakh Cr)
Road Length (Million Km)	5.5	5.7	5.9	6.1	6.3	15.2
Railway Electrification (%)	25	38	58	75	93	8.5
Internet Users (Crore)	35	50	70	88	97	12.8
Mobile Towers (Lakh)	18	22	28	35	42	6.3
Startup Recognition (Lakh)	0.2	0.3	0.5	0.8	1.0	2.5

Source: Ministry of Road Transport & Highways, Ministry of Railways, TRAI & DPIIT, Government of India

Table 9 presents India's impressive infrastructure expansion from 2015 to 2024 which has been a critical driver of economic growth and digital transformation. Road length increased from 5.5 to 6.3 million kilometers reflecting sustained investments in highway construction and rural road connectivity. Railway electrification registered a rapid surge from 25 percent in 2015–16 to 93 percent in 2023–24. This transition not only enhanced energy efficiency but also aligned with India's clean energy commitments and reduced dependence on fossil fuels. Digital infrastructure witnessed a dramatic transformation. Internet users almost tripled from 35 crore to 97 crore while mobile towers more than doubled from 18 lakh to 42 lakh. The startup ecosystem also grew remarkably with official recognition of startups rising from just 0.2 lakh in 2015–16 to 1.0 lakh in 2023–24. Combined with an investment base of ₹2.5 lakh crore.

SDG 10: Reduced Inequalities - Building an Inclusive Society for All

India's plan to bridge the gap between rich and poor people includes dealing with differences in income, social status, location and opportunities. The Gini coefficient has gone down which shows that the distribution of income is getting better (DD News 2025). But the concentration of wealth is still high because the top 1% controls a large part of the country's wealth. Social protection systems have grown a lot covering more than 94 crore people through a number of programmes (PIB, 2024). The Direct Benefit Transfer system has helped people get more access to money by sending over ₹34 lakh crore directly to people through Jan Dhan accounts. The Post-Matric Scholarship program helps SC/ST students get into college and the Stand-Up India initiative helps women and other groups that are not well-off start their own businesses (PIB 2024).

Table: 10 Trends in Inequality and Social Protection in India

Inequality Dimension	**2015-16**	**2017-18**	**2019-20**	**2021-22**	**2023-24**
Gini Coefficient	0.35	0.35	0.34	0.33	0.32
Bottom 40% Income Share (%)	19.2	19.5	19.8	20.1	20.8
Rural-Urban Income Ratio	2.8	2.7	2.6	2.5	2.3
Interstate PCSDP CV	0.68	0.67	0.66	0.65	0.63
Social Security Coverage (%)	28	38	52	68	85

Source: Ministry of Finance, NITI Aayog & NSSO

it is clear from the data presented in table that India has reported big improvements in income distribution and social security coverage between the year 2015 to 2024. The bottom 40% of households' share of income rose from 19.2% to 20.8% which shows that growth is becoming more inclusive. The rural-urban income ratio went from 2.8 to 2.3. The coefficient of variation of per capita state domestic product is also gone down from 0.68 to 0.63. The proportion of individuals receiving social security benefits rose significantly from 28% to 85%.

SDG 11: Sustainable Cities and Communities - Managing Urbanization for Inclusive Development

The transformation of urban areas in India presents a duality of challenges and opportunities. It is projected that by the year 2030, the urban population will attain a figure of 60 crore, as reported by the Press Information Bureau (PIB) in 2024.The Smart Cities Mission helps 100 cities improve their infrastructure, make digital governance more sustainable and provide better services to citizens. The Pradhan Mantri Awas Yojana (Urban) has approved more than 1.18 crore homes and built more than 80 lakh units. The metro rail has been expanded to 21 cities, covering more than 900 km and the infrastructure for bus rapid transit, electric buses and non-motorized transport has been improved which encourages sustainable travel. The National

Electric Mobility Mission helps cities get more people to use electric vehicles. The Swachh Bharat Mission (Urban) modernized waste management which increased the amount of solid waste that was processed from 18% to 68%. This was done by building new waste-to-energy plants, recycling units and decentralized treatment facilities.

Table: 11 Trends in Urban Development Indicators in India with 2030 Targets

Urban Indicator	2015-16	2017-18	2019-20	2021-22	2023-24	2030
Urban Population (%)	32.5	33.2	33.8	34.5	35.2	40.0
Slum Population (%)	23.5	22.1	20.8	19.2	17.5	15.0
Pucca Houses (%)	68.0	72.0	76.0	80.0	85.0	95.0
Sewerage Coverage (%)	32.0	38.0	45.0	52.0	60.0	80.0
Metro Rail Coverage (Cities)	12	15	18	20	21	30

Source: Ministry of Housing and Urban Affairs & NITI Aayog (2025)

Table 11 shows that India's urban population went from 32.5% in 2015–16 to 35.2% in 2023–24. This shows that urbanization is still happening. The percentage of people living in slums went down from 23.5% to 17.5% which shows how good housing programs like PMAY-Urban and state slum redevelopment projects can be. The number of pucca houses went up a lot which means that housing is less likely to be damaged. The increase in sewerage coverage from 32% to 60% indicates progress however it remains below the target of 80% set for 2030. The extension of the metro rail network from 12 to 21 cities has markedly improved urban mobility.

SDG 12: Responsible Consumption and Production - Transitioning to a Circular Economy

India's approach to responsible consumption and production is based on the principles of the circular economy which include reducing waste and using resources in a way that doesn't harm the environment. The Waste Management Rules 2016 set out rules for how to handle and get rid of trash and investments in waste management infrastructure and policy changes led to an increase in the processing of municipal solid waste (PIB, 2024). The

Har Ghar Tiranga effort along with other public awareness initiatives targeted at reducing single-use plastics has considerably raised public knowledge of sustainable consumption behaviors (PIB 2024).

Table: 12 Progress in Waste Management Indicators in India

Waste Management Indicator	2015-16	2017-18	2019-20	2021-22	2023-24
MSW Processing (%)	18.0	28.0	42.0	58.0	68.0
Plastic Waste Recycling (%)	35.0	42.0	48.0	55.0	62.0
E-waste Collection (%)	12.0	18.0	25.0	35.0	45.0
Composting (% of organic waste)	15.0	22.0	28.0	35.0	42.0
Industrial Water Recycling (%)	28.0	32.0	38.0	45.0	52.0

Source: Ministry of Environment, Forest and Climate Change & NITI Aayog (2025)

Table 12 shows that India's waste management has improved a lot from 2015–16 to 2023–24. The Swachh Bharat Mission and more efforts to turn waste into energy and separate it into different types of waste led to an increase in the processing of municipal solid waste from 18% to 68%, but a lot of urban waste still isn't treated which shows that we need more decentralized facilities. Recycling plastic waste went from 35% to 62%. Formal collection centers and stricter rules helped e-waste collection grow from 12% to 45% almost four times as much. More decentralized composting units made composting organic waste better going from 15% to 42%. Recycling of industrial water also went up from 28% to 52%.

SDG 13: Climate Action - Leading Global Climate Response

India has become a world leader in climate action by setting high goals and keeping the economy growing at the same time. The National Action Plan on Climate Change (PIB, 2024) is a comprehensive plan that brings together climate concerns from all sectors and levels of government through specific missions on solar energy, energy efficiency, sustainable habitats, water, agriculture and ecosystems. The country has successfully lowered the amount of greenhouse gases it emits per unit of GDP, going beyond its goals while keeping emissions per person well below the global average (PIB, 2024). India supports state-level projects, early warning systems and climate-resilient practices to help people deal with the effects of extreme weather and long-term climate change (PIB, 2025).

Table: 13 Trends in Key Climate Indicators in India

Climate Indicator	2015	2017	2019	2021	2023	2024
Forest Cover (%)	21.3	21.5	21.7	21.9	22.5	24.6
GHG Emissions (Mt CO2e)	2,650	2,720	2,790	2,720	2,850	2,920
Renewable Energy (GW)	39	57	82	110	180	220
Carbon Sink (Mt CO2)	485	495	510	522	535	550
EV Sales (Units)	25,000	56,000	1.2L	3.3L	8.5L	12.8L

Source: Ministry of Environment, Forest and Climate Change; MNRE; MoRTH (2025)

Table 13 shows that the forest cover grew steadily from 21.3% to 24.6% due to afforestation and forest management programs under Green India Mission. This rise in carbon sink capacity from 485 Mt CO_2 in 2015 to 550 Mt CO_2 in 2024 helped Nationally Determined Contributions. Even though this happened greenhouse gas emissions went up from 2,650 Mt CO_2e in 2015 to 2,920 Mt CO_2e in 2024 because of more industry and energy demand. There was a temporary drop in 2021 because of the COVID-19 slowdown but then emissions went back up showing that it is hard to separate emissions from economic growth. From 39 GW in 2015 to 220 GW in 2024 renewable energy capacity grew quickly due to leadership in deploying solar and wind power and progress toward the 500 GW non-fossil fuel target by 2030. Electric vehicle sales went up from 25,000 in 2015 to almost 1.3 million in 2024.

SDG 14: Life below Water - Protecting Marine and Coastal Ecosystems

India is making more effort into protecting its oceans to show how important they are for long-term growth. The Blue Revolution project supports the growth of sustainable aquaculture for better management of marine capture fisheries and improvements to the value chain. Mangrove conservation programmes also help protect the coast and preserve biodiversity (PIB, 2024). The Marine Fisheries Policy 2017 delineates regulations for deep-sea fishing and advocates for community-based management strategies that foster local stewardship and responsible practices (PIB, 2024).

Table: 14 Trends in Key Marine and Coastal Indicators in India

Marine Indicator	2015-16	2017-18	2019-20	2021-22	2023-24	Target 2030
Fish Production (MT)	10.1	11.5	13.8	15.2	16.2	20.0
Marine Protected Areas (%)	12.0	13.2	14.5	15.2	16.0	20.0
Mangrove Cover (Sq Km)	4,975	4,992	5,017	5,045	5,078	5,500
Coastal Pollution Index	3.2	3.0	2.8	2.6	2.4	2.0
Fisher Welfare Schemes Coverage (%)	45	52	62	72	82	95

Source: Ministry of Fisheries, Animal Husbandry & Dairying; Ministry of Environment, Forest and Climate Change (2025)

Table 14 shows that India's marine and coastal sustainability has improved from 2015-16 to 2023-24 as the fish production has gone up from 10.1 MT to 16.2 MT. The increase in marine protected areas from 12% to 16% shows a stronger commitment to biodiversity and SDG 14. The Coastal Pollution Index's drop from 3.2 to 2.4 shows that pollution control is getting better. The PM Matsya Sampada Yojana and subsidized insurance programmes helped fishing communities' social security and resilience by almost doubling the number of people who were covered by fisher welfare from 45% to 82%.

SDG 15: Life on Land - Conserving Biodiversity and Ecosystem Services

India's efforts to protect biodiversity and restore ecosystems on land have made great strides. The area of protected land has grown a lot which shows that community-based conservation and scientific management are working as the rise in the number of tigers (PIB, 2024). The Green India Mission and other forest conservation programmes work to stop deforestation and encourage afforestation. They also have compensatory afforestation schemes that keep or increase forest cover when land is taken for development (World Economic Forum [WEF], 2022). The Biological Diversity Act 2002 supports these efforts by promoting conservation, sustainable use and fair benefit-sharing. Community-conserved areas, sacred groves and agro-biodiversity programmes enhance formal conservation initiatives in agricultural landscapes (PIB, 2024).

Table: 15 Conservation and Biodiversity Indicators in India with Global Target (2030)

Conservation Indicator	2015-16	2017-18	2019-20	2021-22	2023-24	2030
Protected Area (% of land)	5.0	5.4	6.1	6.8	7.2	17.0
Tiger Population	2,226	2,500	2,967	3,100	3,167	4,000
Elephant Population	27,312	27,500	27,785	28,064	28,342	30,000
Forest Cover (Million Ha)	70.1	70.8	71.2	71.7	72.8	80.0
Tree Cover Outside Forests (%)	2.9	3.1	3.3	3.5	3.8	5.0

Source: Ministry of Environment, Forest and Climate Change; National Tiger Conservation Authority; Project Elephant (2025).

Table 15 shows how India has improved its conservation and biodiversity from 2015–16 to 2023–24 as the area of protected has gone up from 5.0 percent to 7.2 percent, however, this is still below the global goal of 17%. Tiger conservation was very successful with the population growing from 2,226 to 3,167. India is now home to more than 70% of the world's wild tigers. The number of elephants also steadily rose from 27,312 to 28,342. Afforestation, collaborative forest management and natural regeneration contributed to the expansion of forest cover from 70.1 million hectares to 72.8 million hectares. Agroforestry and urban greening contributed to an increase in tree cover outside of forests from 2.9 percent to 3.8 percent.

SDG 16: Peace, Justice and Strong Institutions - Strengthening Governance for Sustainable Development

The use of technology in service delivery, the increase in transparency and the introduction of judicial reforms have all had a crucial impact on governance system of India. The improvement in crime management and the increased handling of cases through e-Courts indicate that initiatives aimed at reinforcing the rule of law; and enhanced institutional capacity are yielding positive results (PIB 2024). Judicial reforms are meant to speed up the process of getting cases heard and make it easier for people to attain justice by allowing online processes and encouraging alternative dispute resolution methods like Lok Adalats and mediation centers (PIB, 2024).

Table: 16 Governance and Institutional Performance in India

Governance Indicator	2015-16	2017-18	2019-20	2021-22	2023-24
Crime Rate (per 100,000)	379	365	358	355	353
Case Disposal Rate (%)	12.0	24.0	38.0	48.0	56.0
RTI Applications (Lakh)	12.5	15.2	18.7	22.3	25.8
Online Services (Number)	450	850	1,450	2,100	2,300
Digital Transactions (Crore)	100	200	450	750	1,200

Source: National Crime Records Bureau (NCRB), Central Information Commission (CIC), Ministry of Electronics & IT, Reserve Bank of India (2025)

The table shows that India's governance performance steadily improved between 2015–16 and 2023–24 as shown by a number of key indicators as the overall crime rate went down from 379 to 353 per 100,000 people. The case disposal rate went up from 12% to 56% due to digital case management, fast-track courts and e-filing. The number of Right to Information applications more than doubled from 12.5 lakh to 25.8 lakh. This shows that more people are getting involved with digital governance progressed swiftly as the quantity of online public services increased from 450 to 2,300; accompanied by a twelvefold escalation in digital transactions rising from 100 crore to 1,200 crore propelled by UPI and Aadhaar-enabled services.

SDG 17: Partnerships for the Goals - Mobilizing Resources and Cooperation

India's strategy for SDG 17 focuses on improving international cooperation, strengthening the mobilization of domestic resources and encouraging partnerships between multiple stakeholders. Official Development Assistance has gone up a lot and the SDG financing gap has gone down a lot (PIB, 2024). India's international cooperation is mostly about sharing technology, building capacity and sharing knowledge. South-South cooperation and leadership in global sustainable development initiatives like the International Solar Alliance are two examples of this (PIB, 2024).

Table: 17 Partnership and Resource Mobilization Indicators in India

Partnership Indicator	2015-16	2017-18	2019-20	2021-22	2023-24
Tax-to-GDP Ratio (%)	16.6	17.1	17.8	18.0	18.2
ODA Received (USD Bn)	1.2	1.8	2.2	2.5	2.8
FDI Inflows (USD Bn)	44.0	61.0	74.0	83.0	95.0
Green Bond Issuance (USD Bn)	0.5	2.1	4.8	8.2	12.5
PPP Projects (Number)	856	982	1,124	1,285	1,458

Source: Ministry of Finance, Department for Promotion of Industry and Internal Trade (DPIIT), Reserve Bank of India, World Bank, SEBI (2025)

The table shows that the governance indicators of India have reported steady progress in institutional accountability and efficiency from 2015–16 to 2023–24 as the crime rate went down a little from 379 to 353 per 100,000 people during this period. Judicial efficiency has improved with case disposal rates have increased from 12% to 56% due e-courts and alternative dispute resolution mechanisms. The number of Right to Information applications went from 12.5 lakh to 25.8 lakh. Digital governance has also made huge strides as online public services grew from 450 to 2,300 and digital transactions grew twelvefold from 100 crore to 1,200 crore.

Comparative Analysis of State and Union Territory Performance

The SDG India Index demonstrates that sustainable development performance varies across states and union territories owing to differences in development routes, resources and policies. Kerala and Uttarakhand had the highest scores of 79 followed closely by Tamil Nadu, Goa and Himachal Pradesh that indicates strong governance, human development and institutional competence. Southern and western states often outperform others due to greater infrastructure and social outcomes whereas northern and eastern states like as Bihar, Jharkhand and Nagaland have issues in poverty, infrastructure and governance (The Print, 2024). State performance is higher in access-oriented categories such as water, sanitation and power but weaker in outcome-based sectors such as learning, nutrition and gender equality. Urban regions outperform rural ones while rural development efforts have helped to close the difference. Kerala and Uttarakhand have maintained their leadership positions due to persistent investments in education, healthcare and environmental conservation. Tamil Nadu and Goa have made consistent improvement whereas Bihar and Jharkhand have made moderate increases. Uttar Pradesh's significant improvement demonstrates the potential for large states to progress with comprehensive reforms and proper resource allocation (NITI Aayog, 2024). (Table: 18)

Table: 18 SDG India Index – State/UT Performance Categories

State/UT Category	Average Score 2023-24	Score Range	Number of States	Key Characteristics
Front Runners (65-79)	72.5	65-79	32	Good performance across goals
Performers (50-64)	58.2	50-64	4	Modest progress, targeted intervention needed
Aspirants (0-49)	-	-	0	None in this category
Best Performers	77.8	75-79	8	Kerala, Uttarakhand, Tamil Nadu, Goa, HP
Lowest Performers	60.7	57-64	5	Bihar, Jharkhand, Nagaland, Meghalaya

Source: NITI Aayog, SDG India Index Report 2024

Conclusion

India’s SDG journey from 2015 to 2024 illustrates the potential for rapid transformation but it faces challenges such as regional variations, incomplete data and insufficient funding. To address variations in development between states, we must establish policies tailored to each state and make better use of available resources. Notable progress has been achieved in reducing multidimensional poverty, expanding access to basic services and accelerating renewable energy deployment. The institutional architecture led by NITI Aayog and reinforced through competitive federalism, has created accountability and incentivized state-level innovation, offering a replicable model for other large developing nations.Persistent challenges remain, particularly regional disparities, malnutrition, gender inequality and environmental stress, compounded by a financing gap of nearly USD 350 billion. Meeting the 2030 targets will require innovative financing, stronger private sector engagement and adaptive governance that integrates inclusivity with resilience. India’s experience affirms that sustainable development is a socio-political process rather than a technical one and its trajectory toward 2047 will continue to shape not only national development but also global progress toward a more equitable and sustainable future.

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2.

BRIDGING SCIENCE AND SUSTAINABILITY: LIFE-SCIENCE CONTRIBUTIONS TO INDIA'S SUSTAINABLE DEVELOPMENT GOALS ACHIEVEMENTS

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Abstract

India’s life-science sector is pivotal in advancing the Nation's Sustainable Development Goals (SDGs). This diverse sector, encompassing biotechnology, agriculture, healthcare, and environmental innovation, not only drives economic growth but also significantly improves the quality of life for millions. This article examines how progress in these fields is creating tangible impacts in both rural and urban communities. By reviewing current research, policies, and field evidence from across the country, it highlights success stories, identifies ongoing challenges, and proposes strategies for more equitable and sustainable growth. Each section integrates updated data to demonstrate how science is empowering citizens, supporting local solutions, and fostering inclusive social change.

Keywords: Life Sciences, Sustainable Development, SDGs, Science Policy & Innovation.

Introduction

Innovation in life sciences is reshaping India's development trajectory by translating global scientific discoveries into practical, localized solutions. Over the past decade, intensified research in public and private laboratories has yielded critical breakthroughs, including new vaccines, biofortified crops, and eco-friendly waste treatment methods. These advancements are increasingly moving from laboratories into Indian homes, farms, and workplaces, driven by a combination of strategic policy and active community participation. Together, these forces are enabling science to address pressing national challenges like malnutrition, disease outbreaks, and environmental degradation. However, the benefits of these innovations are not yet distributed equally. Gaps in policy, funding, and last-mile access continue to limit their full impact. Bridging these gaps requires sustained research support, regulatory reforms, and stronger mechanisms to connect scientific solutions with community needs.

India's progress is also linked to its expanding role in global research. The country is participating in major international projects like the Genome India initiative while simultaneously cultivating its domestic research capabilities. A blend of traditional knowledge and modern science, energized by a vibrant start-up ecosystem, has produced novel solutions that reflect India's unique context and offer valuable models for other developing nations. One powerful example is the use of biotechnology to enhance agricultural resilience. Indian researchers are developing climate-smart seeds and soil-friendly practices that help farmers contend with rising temperatures and water scarcity. These solutions not only boost crop yields but also reduce pressure on natural resources. When combined with digital tools for market access and weather forecasting, they exemplify how life sciences can build a future where rural communities thrive while protecting the environment.

Objectives of the Study

This study aims to:

Explore how life-science innovations in India contribute to the SDGs, with a focus on agriculture, health, water, and the environment.

Assess the institutional links between policy, research, and communities by reviewing literature and field evidence.

Identify key challenges, including regulatory barriers, funding gaps, and social exclusion.

Offer policy recommendations to scale inclusive life-science solutions and emphasize the role of community engagement and ethics in ensuring sustainable impact.

Review of Literature

A growing body of research demonstrates that a robust interface between science and policy is crucial for driving sustainable development in India. Prabhakaran et al. (2021) highlight how the rapid response to COVID-19 was enabled by close coordination among government agencies, research institutions, and private firms. Similarly, Bouis and Saltzman (2017) document how biofortification programs, which added vital nutrients to staple crops, have helped improve nutrition in communities with widespread micronutrient deficiencies. Reports from institutions like the Institute for Studies in Industrial Development (ISID) and the Indian Council of Medical Research (ICMR) underscore the role of digital infrastructure—such as the Ayushman Bharat Digital Mission and the Digital Agri Stack—in disseminating health and agricultural innovations. However, they also caution that the success of these platforms depends on continued policy support, enhanced digital literacy, and adaptive regulation.

Despite these advances, significant challenges related to equity and inclusion persist. Singh et al. (2021) and the OECD (2022) note that deep-rooted issues, such as the underrepresentation of women in science and the uneven distribution of research facilities, hinder the nationwide reach of new technologies. Patil (2022) adds that public mistrust and cultural factors can lead to the rejection of promising biotech solutions. Field studies by ICRISAT (2024) and the Central Ground Water Board (CGWB, 2024) show that successful interventions typically involve co-designing solutions with target communities, blending expert knowledge with local experience. This makes a compelling case for policies and programs that are flexible, inclusive, and context-specific.

Recent research also points to the rising importance of community-driven innovation. Many rural and semi-urban regions are becoming incubators for life-science applications designed with the end-user in mind. These include solar-powered cold storage units for vaccines and crops, portable diagnostic kits, and water purification systems using low-cost biofilters. Such solutions, often co-developed with local universities, non-profits, and self-help groups, prove that innovation is most effective when it is grounded in people's everyday needs.

Finally, scholars are calling for greater integration of India’s traditional knowledge systems with formal science. Practices in Ayurveda, organic farming, and water conservation offer valuable insights often overlooked by mainstream research. Bridging this gap through mutual respect and open dialogue can enrich life-science innovation and help create development models that are both modern and deeply rooted in Indian heritage. The future of sustainable development in India depends not just on scientific progress, but on how well that progress is shared, understood, and embraced by all.

The Science–Policy Bridge

The COVID-19 pandemic severely tested India's science-policy processes, yielding valuable lessons for advancing the SDGs. Coordination between policymakers and scientists improved through several mechanisms. For instance, embedding scientific advisers within ministries facilitated timely data sharing, while platforms like the NITI Aayog SDG Dashboard allowed officials to monitor local initiatives in near real-time (Prabhakaran et al., 2021; OECD, 2022; NITI Aayog, 2023). States like Kerala and Telangana have become models of effective science-policy collaboration, institutionalizing expert committees and regular policy dialogues (Singh et al., 2021).

However, preparedness and resources vary across states. In some regions, science advisory committees formed during the crisis were reactive and short-lived, highlighting the need for more permanent, forward-thinking systems. Experts argue that evidence-informed decision-making must become a routine part of governance, supported by capacity building, institutional memory, and community oversight. Establishing internal "science cells" in key departments and investing in evaluation can help make innovation policy more coordinated and responsive. To sustain the science-policy nexus for the SDGs, India must create open forums where researchers, officials, and community groups can collaboratively review progress and plan future actions. Fostering clear science communication and robust data systems will be crucial for translating new discoveries into tangible improvements in people’s lives.

Feeding a Nation: SDG 2 (Zero Hunger)

India's agricultural sector is undergoing a transformation driven by life-science innovations. The integration of iron-rich pearl millet and vitamin A-enriched sweet potatoes into public food programs has helped improve nutrition, particularly for children and low-income families (ICRISAT, 2024; Bouis & Saltzman, 2017). In flood-prone regions, farmers are adopting CRISPR-edited rice varieties that offer enhanced resilience to extreme weather, strengthening their defense against climate-related crop loss (as noted in ICAR-NRRI research goals). Simultaneously, the Digital Agri Stack is modernizing how farmers access advisory services, market information, and government support, delivering timely information in local languages and bridging communication gaps (ISID, 2023).

Still, significant hurdles remain. Lengthy regulatory approvals for genetically engineered (GE) crops like GE mustard slow the translation of scientific breakthroughs to the field (HarvestPlus, 2017). Many small and marginal farmers face barriers in accessing certified seeds and new technologies, while public apprehension about genetically modified foods persists (NFHS-5, 2021; Patil, 2022). Yet, local initiatives like the women-led seedbanks in Chhattisgarh demonstrate how innovation rooted in community needs can create lasting change. Linking such efforts to government procurement and institutional markets provides a powerful model for scaling up impact. The shift toward digital farming and climate-smart practices is also creating new opportunities for smallholders. Biofertilizers and community-based extension services are reducing dependence on chemical inputs, while participatory approaches like farmer-led field trials ensure that innovation is inclusive and effective.

Health for All: SDG 3 (Good Health and Well-being)

Health innovation in India reflects a balance between global leadership and public welfare. As one of the world's largest vaccine producers, India was instrumental during the COVID-19 pandemic, supplying vaccines both domestically and globally (Ajfand, 2022). At home, the Ayushman Bharat Digital Mission and expanded immunization drives have extended healthcare services to millions, improving access and reducing out-of-pocket expenses. However, coverage remains uneven, especially in tribal and remote areas where infrastructure and awareness are limited. Closing these gaps requires targeted public health campaigns, culturally sensitive communication, and mobile health units to reach the last mile. Ambitious programs like the Genome India initiative, which maps the country's genetic diversity, are paving the way for personalized medicine, promising more precise management of chronic and infectious diseases (Economic Times, reporting on the initiative).

India's digital health push is transforming care delivery. Digital health IDs, integrated electronic health records, and AI-powered decision-support tools are streamlining patient care and reducing delays. Yet, challenges like poor internet connectivity and power outages in rural areas threaten to create a digital divide (National Health Authority, 2024). To prevent this, India must strengthen its digital infrastructure, expand its bioinformatics workforce, and enforce robust data privacy protections. Integrating India's vast network of community health workers with these digital tools is key to bringing tech-enabled care to people in a familiar, trusted manner.

New platforms in telemedicine and wearable diagnostics are further bridging access gaps, allowing for real-time patient monitoring and enabling people in remote areas to receive care without arduous travel. To scale these benefits equitably, India must move beyond technology deployment to invest in digital literacy and embed ethical standards in health-tech development. The ultimate goal must be equity—ensuring that innovation improves health for all, regardless of geography, income, or social status.

Water and Sanitation: SDG 6 (Clean Water and Sanitation)

Technological advancements are revolutionizing India's management of water safety and sanitation. In rural Rajasthan, water quality sensors combined with digital alerts enable local operators to detect contamination early, preventing public health crises (NITI Aayog, 2023). In Tamil Nadu, textile industries are adopting microalgae bioreactors to treat wastewater, reducing pollution from industrial discharge (IIT-Madras, 2023). These examples show how applied science can protect both human health and the environment.

However, challenges persist, particularly for marginalized communities. Over 40% of rural habitations face health risks from high groundwater fluoride levels (CGWB, 2024). Often, available technologies are rendered ineffective by poor maintenance and inadequate training. Lasting change requires not just better infrastructure but also governance reforms that ensure funding for maintenance, local accountability, and community participation. A promising approach combines high-tech solutions with community-led monitoring, empowering residents to manage their own resources.

Expanding the use of decentralized water purification units and affordable point-of-use biosensors can be a game-changer for remote villages. For these tools to succeed, communities must be empowered to manage their water systems, supported by clear data, training, and reliable maintenance. Paired with strong local governance and advanced data analytics for early warning, these technologies can accelerate India's progress toward universal access to clean water and sanitation.

Planetary Health: SDGs 13 & 15 (Climate Action & Life on Land)

India's environmental science advancements demonstrate a growing synergy between biodiversity, climate action, and life-science innovation. Carbon capture start-ups are converting industrial emissions into valuable products like biofuels, reducing pollution while creating green jobs (IIT-Bombay, 2024). In conservation, portable DNA sequencers allow forest rangers to quickly identify species and gather anti-poaching evidence, improving enforcement and conviction rates (DBT, 2023). These tools show how life sciences are being integrated into practical efforts to protect India's natural heritage.

Despite these advances, progress is often hampered by fragmented governance and limited funding. Overlapping mandates among ministries for agriculture, environment, and climate lead to inefficiency and missed opportunities (MoEFCC, 2025). Experts call for better funding alignment and unified funds for "nature-based solutions" that span sectors. Scientific progress in fields like restoration ecology can only achieve its potential if backed by robust data systems, local training, and policies that prioritize community involvement.

Innovative community-led projects are already paving the way. Locally managed habitat restoration and payment-for-ecosystem-services schemes create conservation models that align with livelihoods. These efforts prove that combining local action with advanced genomic and environmental technologies can multiply impact. Building platforms for collaboration among communities, scientists, and policymakers—supported by consistent funding—will be crucial for India's environmental resilience.

Financial and Systemic Enablers- Money Matters

Financial support is critical for scaling life-science solutions for the SDGs. India's R&D spending in this area remains below 1% of its GDP, limiting the reach of promising innovations (OECD, 2022). While government funding, notably through the Biotechnology Industry Research Assistance Council (BIRAC), has been vital for start-ups, scaling is hindered by regulatory delays and a lack of late-stage funding (BIRAC, 2023). Many innovations are trapped in the "valley of death" between initial research and market application.

Blended finance models, which combine philanthropic and private capital, are emerging to fund high-impact projects like rural health supply chains (BIRAC, 2023). To be effective, these models require greater integration into national budgets, supported by clear regulations and performance metrics. Policy experts advocate for new tax credits, risk-sharing instruments, and targeted funds for women-led and social enterprises. A stable policy environment, equitable funding distribution, and strong accountability mechanisms are essential for fostering a thriving and resilient innovation ecosystem.

Inclusion and Ethics

Equity and ethics are central to India's life-science evolution. Despite policy improvements, groups such as women, tribal communities, and people from lower-income backgrounds remain underrepresented in scientific leadership (ICMR, 2023). Efforts to improve grant access, create safer work environments, and expand mentorship are underway, but progress is uneven. The adoption of CARE principles (Collective Benefit, Authority to Control, Responsibility, Ethics) for research has improved community consent processes, but more training is needed to help local institutions navigate complex ethical guidelines.

Ethical concerns are particularly acute in genetic research and digital health, where questions of data ownership, usage, and benefit-sharing are paramount. Participatory models like citizen science and community advisory boards can enhance transparency and accountability. To build long-term trust, India must strengthen its ethical review systems and protect individual rights. This includes expanding STEM education in underserved areas, providing leadership training for women, and embedding clear equity goals into all major funding and regulatory programs.

Voices from the Field

Real-world impact is best understood through the experiences of those on the ground.

- In Jalna, Maharashtra, cotton farmers report lower pesticide costs due to Bt cotton but also express concern about new pest outbreaks, indicating a need for better extension support.
- In Phagi, Rajasthan, water pump operators note that Bluetooth-enabled monitors have shifted local attitudes from blame to shared problem-solving, leading to proactive maintenance and greater community trust (NITI Aayog, 2023).
- Women's self-help groups in Chhattisgarh, who manage local seed banks, speak of increased community status and improved household nutrition resulting from their control over climate-resilient, nutritious crops.
- Rural health workers testing digital health IDs find the tools simplify their work but highlight the critical need for better training and reliable internet connectivity.

These narratives underscore a vital truth: technology alone is insufficient. Sustainable innovation requires strong partnerships, continuous feedback, and a deep understanding of local contexts.

Policy Recommendations to Catalyze Progress

To fully harness life-science breakthroughs for the SDGs, India should adopt strategic policy reforms:

Streamline Regulation: Create a single-window clearance system for biotech innovations to reduce delays and provide a clear path to market.

Increase R&D Investment: Raise public R&D spending to at least 1.5% of GDP, with a dedicated focus on late-stage development and community-led projects.

Strengthen State-Level Coordination: Establish SDG Life-Science Cells in each state to coordinate cross-departmental efforts, track data, and share best practices.

Targeted Financial Tools: Scale blended finance models and create dedicated funds to support women-led and rural innovators, fostering a more inclusive ecosystem.

Prioritize Nature-Based Solutions: Launch a unified National Fund for Restoration that integrates funding for climate, biodiversity, and water initiatives.

Foster Open Science: Promote open-access data platforms and digital repositories to make research more inclusive and accelerate progress across all SDGs.

Conclusion

India's journey toward the 2030 SDGs is inextricably linked to the transformative power of life-science innovation. From enhancing crop nutrition and vaccine access to ensuring cleaner water and restoring ecosystems, scientific advancements are yielding tangible benefits. However, to realize this potential fully, India must address persistent challenges, including regulatory hurdles, funding gaps, and social inequities. This requires flexible, evidence-based policymaking that is responsive to local realities.

Moving forward, greater alignment among government, civil society, and industry is paramount. This requires shared goals, long-term planning, and an unwavering commitment to equity. Scientific innovation must be anchored in ethical governance, public trust, and meaningful community engagement. By ensuring that advances are developed and deployed with transparency and inclusivity, India can convert discovery into equity. In doing so, it can unlock the full potential of its life-science sector and forge a sustainable and prosperous path to 2030 and beyond.

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3.

ADVANCING SUSTAINABLE DEVELOPMENT THROUGH HORTICULTURE IN INDIA

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Abstract

Horticulture is the practice of growing fruits, vegetables, flowers and ornamental plants. It is a key driver of sustainable agriculture and progress toward the United Nations Sustainable Development Goals. This article explores how sustainable horticultural practices tackle global issues like climate change, food insecurity, poverty and environmental decline. Techniques such as organic farming, precision irrigation and integrated pest management boost resource efficiency, cut environmental harm and enhance climate resilience, supporting goals like Zero Hunger, Responsible Consumption, Climate Action, and Life on Land. Horticulture also fuels economic and social growth by creating jobs especially for women with crops generating 2.5 times more employment than cereals and boosting household incomes by up to 35% in some areas. It improves nutrition by providing micronutrient-rich foods that addressing deficiencies for billions. Technologies like IoT sensors and vertical farming optimize yields while reducing resource use with water efficiency rising 5.4% annually and organic horticulture growing 7.1% yearly. However, smallholders face barriers like

limited technology access and financial constraints.India is the second-largest producer of fruits and vegetables in the world. It uses many sustainable farming methods to fight climate change, hunger, poverty and environmental problems. India also accounts for 24 percent of the world's organic fruit and vegetable farming area but still many small farmers in India face challenges in using new technologies and getting financial support.

Keywords: Horticulture, Sustainable Agriculture & Sustainable Development Goals (SDGs)

Introduction

Horticulture plays an important role in both direct and indirect ways in making development more sustainable. With the world's population growing and problems like pollution, loss of biodiversity and climate change increasing, there is a strong need for eco-friendly farming methods like sustainable horticulture. These practices not only help protect nature but also keep our food systems strong. By using modern technology, saving resources like water and energy and helping rural communities—especially small farmers—horticulture supports many Sustainable Development Goals (SDGs), especially SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action) and SDG 15 (Life on Land) (FAO 2020; Lal 2020; Mehta & Kundu 2023).Although horticulture faces big challenges like changing weather, limited natural resources and environmental damage, it also has great potential to solve these issues. With smarter farming methods and better use of resources, horticulture can help protect the environment while still producing enough food. The sector also creates many jobs—especially for women and disadvantaged groups—and provides healthy nutrient-rich food that is essential for a balanced diet and better health (Akramov & Shreedhar 2020; Singh & Mishra 2022).

New technologies like precision farming, climate-smart practices and indoor farming methods such as greenhouses and vertical farms are helping farmers produce more with fewer resources. Tools like IoT sensors, GPS machines and automated systems allow farmers to track and manage crops more efficiently and reduce harm to the environment (Sharma & Singh 2022; van Delden et al. 2021). In fact, horticulture now makes up over 33% of agriculture's contribution to GDP in countries like India and supports millions of jobs worldwide (World Bank 2021; ADB 2020). Combining traditional knowledge with modern science has also helped create solutions that fit local needs and improve both environmental care and community well-being (Verma et al. 2024; FAO & ISHS 2023).

Horticulture plays a major role in India's sustainable development. It makes up over 30 percent of the country's agricultural GDP and provides jobs to nearly 23 million people (Ministry of Agriculture & Farmers Welfare [MAFW], 2023). With growing concerns like climate change, pollution and biodiversity loss, both India and the world need more eco-friendly ways to farm. For India, especially with its 138 million small farmers and dry regions, using resources wisely is very important. Programs like the Pradhan Mantri Krishi Sinchai Yojana and traditional water-saving methods show how India combines global ideas with local needs (Indian Council of Agricultural Research (ICAR, 2022). India's horticulture is growing faster than global agriculture, with a yearly average of 5.7 percent compared to the global rate of 1.9 percent (National Horticulture Board [NHB], 2023; Food and Agriculture Organization [FAO], 2023). Still, challenges like small land holdings, 18 to 30 percent post-harvest losses and limited access to resources for women continue to hold back progress (World Bank, 2021).

Review of Literature

A substantial amount of academic research highlights the critical importance of sustainable horticulture in promoting various Sustainable Development Goals (SDGs). Research indicates that eco-friendly practices, including organic farming, integrated pest management (IPM), precision irrigation and biodiversity conservation, effectively mitigate soil degradation, reduce greenhouse gas emissions, and conserve natural resources, while sustaining agricultural productivity (Bharucha et al., 2020; Lal, 2020; Smith et al., 2021). Emerging technologies such as precision farming and controlled environment agriculture (CEA), including vertical farming and greenhouse systems, facilitate increased yields per unit area while minimizing environmental impact (Sharma & Singh, 2022; van Delden et al., 2021). Sustainable horticulture functions as a systems-based method for enhancing climate resilience, improving resource efficiency and promoting environmental regeneration (FAO, 2020; Mehta & Kundu, 2023).

Horticulture plays a crucial role in employment generation, poverty reduction, and the empowerment of women within socio-economic contexts. Studies indicate that horticultural crops create 2.5 times more employment compared to cereals, with one hectare of vegetable farming providing approximately 1.5 full-time jobs (World Bank, 2021; Singh & Mishra, 2022). Research from Asia and Central Asia indicates that involvement in horticultural value chains can increase household incomes by as much as 35% and improve women's agency in economic decision-making (FAO, 2021; Akramov & Shreedhar, 2020). The sector also facilitates indirect employment in packaging, processing, and marketing. Data from Uzbekistan indicates that horticulture-based initiatives have generated more than 34,500 permanent jobs, with nearly 40% occupied by women (ADB, 2020).

The adoption of sustainable horticulture, despite its numerous benefits, is impeded by technological gaps, restricted financial access, and institutional constraints. Smallholders in developing regions face challenges related to limited access to precision tools, credit, extension services, and quality inputs (Kumar & Patel, 2022; Roy et al., 2021). Scholars recommend focused investments in technology transfer, digital infrastructure, and innovations that are resilient to climate change (Chand et al., 2022; FAO & ISHS, 2023). International collaborations, exemplified by FAO's partnership with ISHS, have facilitated knowledge-sharing networks and South-South cooperation, thereby advancing the integration of horticulture into food systems transformation agendas. The strategic significance of horticulture in promoting sustainable agriculture and resilient livelihoods is evident in these efforts (FAO & ISHS, 2023; Verma et al., 2024).

Numerous studies highlight that Indian horticulture mirrors and sometimes differs from global trends. For instance, India’s IPM adoption rates exceed 65% in major vegetable growing states—higher than the global mean of 45% (ICAR, 2023; FAO, 2023). Technology diffusion, however, remains uneven: about 32% of Indian horticulture uses drip irrigation, compared to 60%+ in Israel, or 45% in Spain (MAFW, 2023; ICAR, 2022; FAO-ISHS, 2023). Women’s labor force participation in Indian horticulture is estimated at 72%, closely mirroring Africa’s 75% but higher than Europe or North America (NHB, 2023; FAO, 2021). Despite India having the world's largest area under organic horticulture (1.71 million ha), only 11% of all horticultural land is farmed organically—a lower proportion than Europe's 18%, but well ahead of most Asian countries (IFOAM, 2023; MAFW, 2023). Comparative evidence suggests that, in India, household incomes from horticulture can rise 28–40% over those from staple crops—akin to global increases (World Bank, 2022; NHB, 2023). However, post-harvest infrastructure and credit access remain larger constraints for Indian smallholders than for farmers in OECD countries (Roy et al., 2021; Kumar & Patel, 2022).

Objectives of the Study

This study aims to assess how sustainable horticultural practices contribute to environmental protection resource efficiency and climate resilience and also examining their social and economic impacts on employment gender inclusion income and smallholder livelihoods. It further seeks to compare India's horticulture sector with global trends in sustainability, productivity, nutrition, security and contributions to the Sustainable Development Goals and to identify key challenges while proposing policy strategies for inclusive and sustainable growth.

Sustainable Horticulture and Its Contribution to Sustainable Agriculture

Sustainable horticulture plays a key role in promoting sustainable agriculture by using eco-friendly methods that protect natural resources and reduce environmental harm. It focuses on practices like organic farming, efficient water use and natural pest control to keep the soil healthy and reduce pollution. These methods help farmers grow crops in a way that supports long-term food production without damaging the environment. Sustainable horticulture also creates jobs, improves rural incomes and supports biodiversity which makes it an important part of achieving goals like zero hunger, climate action and responsible farming. By combining modern technology with traditional knowledge, it offers practical solutions for building a more resilient and productive agricultural system.

Key Sustainable Practices in Horticulture

Sustainable horticulture involves a variety of practices that aim to increase crop production while protecting the environment and ensuring long-term agricultural sustainability. One of the core methods is organic farming that replaces synthetic fertilizers and pesticides with natural alternatives. This approach improves soil health, boosts biodiversity and reduces harmful residues in food (Lal, 2020; Smith et al., 2021). Organic systems have also shown strong potential in capturing carbon and lowering greenhouse gas emissions, achieving yields that are often comparable to conventional farming methods (Mehta & Kundu, 2023). Over the past decade, global organic farming has expanded by more than 20 percent which shows increasing adoption of this practice (FAO, 2020).

Water conservation is another major component of sustainable horticulture. Techniques such as drip irrigation and precision water management have helped farmers reduce water usage by up to 50 percent without sacrificing crop quality (Sharma & Singh, 2022; van Delden et al., 2021). These systems use tools like soil moisture sensors and weather-based scheduling to apply the right amount of water at the right time which is especially important in areas facing drought or water scarcity (FAO & ISHS, 2023). The use of closed-loop hydroponic and recycling systems has further improved efficiency and reduced environmental harm, allowing for high productivity with minimal water waste (World Bank, 2021).

Integrated pest management (IPM) is also essential in reducing pesticide dependence. IPM combines biological, cultural and physical control methods to manage pests in a way that is effective and safe for both crops and ecosystems (Akramov & Shreedhar, 2020). Research shows that IPM can cut pesticide use by up to 80 percent while protecting beneficial insects and improving crop resilience (Singh & Mishra, 2022). Alongside this, crop diversification techniques such as intercropping and polyculture mimic natural ecosystems and improve resilience. These systems enhance nutrient use, stabilize yields under variable conditions and support greater biodiversity within farming landscapes (Verma et al., 2024). Together, these practices create a horticultural system that is not only productive but also aligned with sustainable development. By focusing on soil conservation, smart water use and natural pest control, sustainable horticulture helps to build resilience to climate change and protect the ecosystem. It balances agricultural output with ecological care and promotes a shift toward regenerative farming. These methods, when supported by training, policy reforms and access to technology, hold great potential to transform food systems in both rural and urban contexts (ADB, 2020).

Box:1 Horticulture's Alignment with Sustainable Development Goals (SDGs)

SDG Goal	Contribution of Horticulture
SDG 1: No Poverty	Livelihood and employment generation
SDG 2: Zero Hunger	Improves food availability and nutrition
SDG 5: Gender Equality	Women's empowerment in value chains

SDG 6: Clean Water	Water-efficient methods and pollution reduction
SDG 8: Decent Work	Employment and rural job creation
SDG 12: Responsible Consumption	Resource efficiency and waste reduction
SDG 13: Climate Action	Climate adaptation and mitigation strategies
SDG 15: Life on Land	Biodiversity conservation and ecosystem enhancement

It is clear from the above box: 1 that horticulture plays a strong role in reducing poverty and improving food security by offering better income opportunities and creating more jobs for rural households. In line with SDG 1: No Poverty, horticultural activities provide small farmers with reliable and often higher income compared to traditional crops. These systems also demand more labour which helps to utilize rural workforce more effectively. At the same time, SDG 2: Zero Hunger is supported as fruits and vegetables from horticulture contribute essential vitamins and minerals that improve the quality of diets. By making healthy food more available, especially to vulnerable communities, horticulture helps tackle both hunger and malnutrition.SDG 5: Gender Equality is advanced through horticulture as women make up a large portion of its workforce, especially in planting, harvesting and marketing. Their participation not only boosts household incomes but also increases their role in financial decisions and community involvement. Meanwhile, SDG 6: Clean Water and Sanitation benefits from the use of water-saving technologies such as drip irrigation and moisture sensors. These innovations help reduce water wastage and prevent pollution of water bodies by limiting agricultural runoff, promoting the sustainable use of water resources.

The sector also contributes to SDG 8: Decent Work and Economic Growth by supporting a wide range of jobs in farming, supply chains and markets. It offers employment opportunities to both skilled and unskilled labour and helps keep rural youth engaged in meaningful work. In addition, SDG 12: Responsible Consumption and Production is supported by encouraging natural farming methods like composting, crop rotation and using fewer chemical inputs. These methods make horticulture more resource-efficient and environmentally responsible, helping reduce waste and protect soil health.When it comes to environmental challenges, SDG 13: Climate Action is addressed through horticultural practices that help lower greenhouse gas emissions and improve soil health. Actions like reduced tillage, organic compost use and cover cropping increase the soil's ability to store carbon, making the land more climate-resilient. Lastly, SDG 15: Life on Land is strengthened by avoiding harmful pesticides and promoting diverse planting systems. These practices protect biodiversity, support pollinators and create healthier ecosystems, making horticulture a vital part of sustainable land use and environmental conservation.

Global vs Indian Horticulture: Employment and Economic Trends

The global horticulture sector has shown consistent growth and transformation from 2021 to 2023 across key employment, economic and sustainability indicators. While overall global agricultural employment declined at an annual rate of 1.6%, the share of horticulture in agricultural GDP steadily increased from 31.2% to 33.0%, reflecting a shift toward more intensive and high-value farming systems. India's horticultural sector has experienced remarkable growth in both scale and sustainability over the past decade. The cultivated area expanded from 21.8 million hectares in 2010 to 28.8 million hectares in 2022, marking a 48% increase, while production rose from 240 million tonnes to 355 million tonnes during the same period (MAFW, 2023). Sustainable practices have gained momentum, with drip irrigation now covering 10 million hectares (34% adoption), 1.71 million hectares under organic cultivation, integrated pest management (IPM) applied in more than 65% of vegetable crops and protected cultivation reaching 0.33 million hectares with an annual growth rate of 11.5% (National Horticulture Board [NHB], 2023). Notably, Sikkim has established itself as the world's first fully organic state, serving as a global benchmark for environmentally responsible farming (Food and Agriculture Organization [FAO], 2018). (Table:1)

Table 1. Comparative Horticulture Sector Employment and GDP Indicators

Indicator	India			Global (2023)
	2021	2022	2023	
Horticulture's Share in Agriculture GDP (%)	30.5	31.7	33.1	33.0
Horticultural Production (mntonnes)	320	337	355	2,430

Direct Employment (mn)	22.4	22.9	23.0	860
Water Use Efficiency vs Conv. Farm (%)	45	48	50	50
Organic Area (million ha)	1.62	1.68	1.71	4.8

Sources: NHB (2023), MAFW (2023), FAO (2023), DEFRA UK (2023)

India's horticulture sector has shown strong performance relative to global trends, with its share in agricultural GDP rising from 30.5% in 2021 to 33% in 2023 reflecting an annual growth of 3.1%. Production increased from 320 million tonnes in 2021 to 355 million tonnes in 2023 against a global output of 2,430 million tonnes, highlighting India's faster annual growth rate of 5.7% compared to the global 1.9%. Direct employment expanded modestly from 22.4 million to 23 million workers while global employment declined, showing India's positive trend of 1.7% annual growth against a global fall of 1.6%. Water use efficiency improved steadily from 45% to 50% over the period equaling the global benchmark with a growth of 5.4%. Organic cultivation area expanded from 1.62 million ha to 1.71 million ha, growing at 6% annually which is close to the global pace of 7.1% demonstrating India's rising commitment to sustainable practices.

Table 2: Regional Employment Creation in Horticulture

Region	Employment (millions)	Share of Total Agricultural Employment (%)	Women's Participation (%)	Income Premium vs Traditional Agriculture (%)
Asia	580	41.5	65	35
Africa	220	64.5	75	28
Europe	25	14.7	55	45
Americas	85	22.4	60	40
Oceania	8	18.7	50	38

Sources: FAO (2022), World Bank (2023), ILOSTAT (2022)

Table 2 illustrates the regional dynamics of horticultural employment, revealing both quantitative and qualitative differences in its role across continents. Asia dominates in absolute numbers with 580 million individuals employed, reflecting the region's vast agrarian base and growing diversification into high-value crops. Africa employing fewer people overall, exhibits the highest share of total agricultural employment in horticulture at

64.5%, indicating a structural reliance on the sector for rural livelihoods. Women's participation is consistently strong—reaching 75% in Africa and 65% in Asia—underscoring horticulture's critical role in advancing gender-inclusive employment. Moreover, the income premium compared to traditional agriculture ranges from 28% in Africa to 45% in Europe, highlighting horticulture's potential for improving rural prosperity and economic resilience. These patterns collectively suggest that horticulture not only serves as a key employment generator but also acts as a strategic pathway toward equitable growth and income enhancement in both developing and developed economies.

Sustainability Performance in Indian Horticulture

Sustainability performance in Indian horticulture has advanced steadily across environmental economic and social dimensions. Water use efficiency has improved by about 5.4% annually compared to conventional farming due to the wider adoption of precision irrigation and integrated nutrient management (National Horticulture Board [NHB], 2023). Organic cultivation now accounts for nearly 11% of horticultural land which highlights the rising preference for eco-friendly and chemical-free produce (Food and Agriculture Organization [FAO], 2021). These developments show that India is moving toward production systems that reduce environmental stress while meeting the growing demand at home and abroad. The simultaneous gains in productivity and sustainability strengthen the role of Indian horticulture in building a greener and more climate-resilient agricultural future (Ministry of Agriculture and Farmers' Welfare [MAFW], 2023).

Table: 3 Sustainability Performance Indicators in Indian Horticulture

Practice Category	Adoption Rate in India (%)	Environmental Benefit	Economic Benefit	Social Benefit
Precision Agriculture	32	Saves 38–50% of water	Increases yield by 18–22%	Reduces labor burden
Organic Production	11	Cuts chemical input use by 50%	Earns 23–27% higher prices	Improves health of farm workers
Controlled Environment	1.1	Achieves up to 90% water efficiency	Enables high-value, off-	Provides jobs independent of climate

			season production	
Integrated Pest Management	62	Reduces pesticide use by 55–75%	Lowers input costs	Improves food safety
Climate-Smart Practices	24	Sequesters 0.5–1.3 tons CO_2 per hectare	Enhances climate resilience	Builds adaptive farming capacity

Sources: ICAR (2023), FAO (2023), World Bank (2021)

The sustainability performance indicators in Indian horticulture show that multiple practices are delivering clear environmental economic and social gains. Precision agriculture has been adopted on about 32% of the area leading to 38–50% water savings yield improvements of 18–22% and a reduced labor burden. Organic production now covers 11% of horticultural land which helps cut chemical input use by half generates 23–27% higher market prices and improves the health of farm workers. Controlled environment farming though limited to 1.1% of the area delivers very high-water efficiency of up to 90% allows off-season high-value production and provides stable jobs regardless of climate conditions. Integrated pest management has reached a wide coverage of 62% resulting in a 55–75% reduction in pesticide use lower input costs and better food safety. Climate-smart practices are adopted on 24% of land where they sequester between 0.5 and 1.3 tons of carbon dioxide per hectare strengthen resilience to climate risks and build adaptive farming capacity (Indian Council of Agricultural Research [ICAR], 2023; Food and Agriculture Organization [FAO], 2023; World Bank, 2021).

Horticultural Employment, Gender and Income Trends in India

Horticulture plays a crucial role in India's rural economy, providing extensive employment opportunities and promoting gender inclusion. The sector engages approximately 23 million workers directly, with women constituting a significant 72% of the workforce—one of the highest rates globally. Additionally, horticultural activities offer substantial income advantages, with earnings 28 to 40% higher than those from staple crop farming. This combination of robust employment, strong female participation, and attractive income premiums underlines horticulture's vital contribution to rural livelihoods and inclusive growth in India. (Table: 4)

Table: 4 Horticultural Employment, Women's Participation and Income Premium in India

Year	Employment (million)	Women's Participation (%)	Income Premium (%)
2021	22.4	72	28–40
2022	22.9	72	28–40
2023	23.0	72	28–40

Sources: NHB-2023; Food and Agriculture Organization (FAO), 2022; International Labour Organization Statistics (ILOSTAT), 2022.

Table 4 presents a clear picture of the significant role horticulture plays in India's agricultural sector from 2021 to 2023. It shows that employment in horticulture has steadily increased, reaching around 23 million people, reflecting the sector's capacity to generate widespread job opportunities. What is especially noteworthy is the exceptionally high participation of women, consistently at 72%, which demonstrates horticulture's potential to empower women economically and socially in rural areas. Additionally, workers in this sector benefit from an income premium of 28 to 40 percent compared to those involved in staple crop farming, highlighting horticulture as a more lucrative and sustainable livelihood option. Overall, these figures underscore the importance of horticulture in driving inclusive growth, supporting rural economies and advancing gender equality in India's agricultural landscape.

Horticulture for Micronutrient Security in India

Horticulture serves as a vital component of micronutrient security in India, contributing significantly to the intake of essential vitamins and minerals indispensable for addressing widespread nutritional deficiencies such as malnutrition, stunting and anemia. Fruits, vegetables, leafy greens, and root vegetables provide key micronutrients including vitamin C, vitamin A, iron, potassium, folate and beta-carotene, which are critical for human health and development (National Horticulture Board [NHB], 2023; Ministry of Health

& Family Welfare [MoHFW], 2023; Food and Agriculture Organization [FAO], 2023; Lal, 2020). India's status as the world's second-largest producer of fruits and vegetables underscores its crucial role in combating hidden hunger and improving dietary diversity for millions of people (FAOSTAT, 2023; Indian Council of Agricultural Research [ICAR], 2023). Enhancing horticultural production not only supports nutritional outcomes but also promotes economic growth and rural livelihoods, aligning with broader sustainable development goals (World Bank, 2022; Chand, Raju, & Singh, 2022).

Table 4: Horticulture Contribution to Micronutrient Security

Crop Group	**India Production (mntonnes)**	**Key Nutrients**	**Estimated Population Served (million)**
Fruits	107.2	Vitamin C, Potassium	850
Vegetables	204.6	Vitamin A, Iron, Zinc	1,800
Leafy Greens	8.2	Folate, Iron, Potassium	380
Root Veg.	22.4	Fiber, Beta-carotene	700

Sources: NHB-2023, FAOSTAT- 2023; MoHFH - 2023.

The table illustrates the vital contribution of horticulture to micronutrient security in India, highlighting production volumes for key crop groups in 2023 alongside the essential nutrients they provide and the estimated population benefiting from them. India produced substantial quantities of fruits (107.2 million tonnes) rich in vitamin C and potassium, supporting approximately 850 million people. Vegetables, produced at an even higher volume (204.6 million tonnes), supply critical nutrients like vitamin A, iron, and zinc, reaching nearly 1.8 billion individuals across the country. Leafy greens and root vegetables, though lesser in production (8.2 and 22.4 million tonnes respectively), are crucial sources of folate, iron, fiber and beta-carotene, nourishing hundreds of millions. The estimated population served figures are based on data and nutritional assessments from the Ministry of Health & Family Welfare (MoHFW, 2023) which integrates production statistics from the National Horticulture Board (NHB, 2023) and global agricultural data from FAOSTAT (2023) with dietary intake patterns and micronutrient availability analyses. This comprehensive measure reflects how effectively India's horticultural sector supports public health and nutrition goals by providing widespread access to essential micronutrients critical for combating malnutrition, stuntingsand anemia in its population.

It is clear from the above analysis that sustainable horticultural practices offer vital pathways for achieving multiple Sustainable Development Goals by promoting environmental stewardship, economic resilience and social inclusion. The integration of innovative technologies such as precision and protected cultivation enhances resource-use efficiency and climate adaptability. Horticulture's high nutritional value contributes to global efforts against malnutrition and hunger, especially among vulnerable populations. With the capacity to generate 2.5 times more jobs than cereal production, the sector plays a critical role in poverty reduction and rural development. Its female-dominated workforce, with women comprising 60 to 85 percent of the labor force, presents significant opportunities for gender empowerment and broader social transformation, particularly in developing countries where women's economic roles remain limited by cultural and institutional barriers.

The rapid advancement of precision agriculture has revolutionized horticultural production by enabling farmers to optimize inputs and boost productivity while reducing environmental impact. However, adoption among smallholders is uneven due to high costs, limited technical knowledge and weak support systems. Addressing these challenges requires comprehensive policies that offer financial assistance, training and institutional strengthening. Climate change adds another layer of complexity but also pushes innovation. The development of resilient crop varieties, adoption of controlled environment farming and implementation of water-efficient systems show the sector’s adaptability. For these innovations to reach farmers effectively, collaboration among researchers, policymakers and communities is essential. Moreover, sustainable horticulture depends on robust market integration and value chain development that guarantee fair pricing for producers and quality produce for consumers. Strengthening local value chains and promoting direct-to-consumer models like farmers' markets and community-supported agriculture can boost incomes and system resilience. Supportive policies that provide access to credit, inputs and effective extension services are crucial for scaling up sustainable practices. International partnerships and collaborative research networks are also key, helping to spread knowledge and innovations that drive global progress in sustainable horticulture.

Conclusion

Sustainable horticulture has emerged as a transformative force in advancing environmental health economic development and social equity. This study highlights that by integrating practices such as organic farming precision irrigation integrated pest management and climate-smart agriculture the horticulture sector can significantly enhance resource efficiency while reducing ecological footprints. India's experience illustrates rapid growth in production and employment alongside improvements in water use efficiency and organic cultivation. These gains demonstrate horticulture's potential to address global challenges including food insecurity climate change and gender disparities. Furthermore, the sector's contribution to micronutrient security underscores its critical role in improving public health outcomes across large populations. However persistent barriers such as limited technology access fragmented landholdings and financial constraints especially for smallholders must be addressed through supportive policies institutional strengthening and innovation dissemination.

Looking ahead sustained progress in sustainable horticulture requires a multi-dimensional approach that balances productivity with ecological stewardship and social inclusion. Empowering women and marginalized groups within the horticultural value chains can accelerate rural development and foster equitable growth. Meanwhile investments in research and development advanced technologies and robust market linkages are essential to enhance farmers' resilience amid climatic uncertainties. This study concludes that combining traditional knowledge with cutting-edge innovations along with coordinated efforts among governments private sector and international partners will be pivotal. By scaling inclusive sustainable horticultural systems India and other countries can achieve significant strides toward the Sustainable Development Goals ensuring food security livelihoods and a healthier environment for future generations.

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4.

SUSTAINABLE DEVELOPMENT AND CLIMATE ACTION: AN APPRAISAL OF INDIA'S PROGRESS ON SDG 13

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Abstract

India's dedication to Sustainable Development Goal 13 (SDG 13) on climate action showcases a remarkable and ambitious journey toward climate transition, aiming for net-zero emissions by 2070 while also nurturing its economic growth dreams. This study takes a closer look at how India is moving towards the targets of SDG 13, focusing on the financial needs, policy structures and changes across various sectors that are essential for reaching climate objectives. India stands at 99th out of 167 countries in the 2025 SDG Index, showcasing notable progress in renewable energy deployment—hitting 50.07% non-fossil fuel capacity five years earlier than planned—however, SDG 13 indicates a trend of "decreasing with challenges." India needs about USD 170 billion each year until 2030 and a total investment ranging from USD 10.1 to 15.7 trillion by 2070 to fulfill its climate commitments. Quantitative modeling suggests that climate change might lead to a reduction in India's GDP by 2.6–13.4% by the year 2100, with every degree Celsius increase potentially resulting in about a 2.5% loss in GDP growth. Success depends on speeding up finance mobilization, improving state-level implementation and weaving climate considerations into economic planning processes (Sami et al., 2017; UNDESA, 2025; Kumar & Maiti, 2024).

Keywords: SDG 13, climate action, climate change, & sustainable development.

Introduction

SDG 13 calls for urgent action to combat climate change and its wide-ranging impacts while representing a critical nexus between environmental sustainability and economic development (NITI Aayog, 2025). For India, the challenge is particularly complex as it is now the world's most populous nation and the third-largest greenhouse gas emitter. The country must balance the imperative of reducing emissions with the equally pressing need to sustain robust economic growth that can support poverty reduction, industrial expansion, and social welfare. In this context, India's Nationally Determined Contributions (NDCs) updated in 2022 mark a significant step forward. They commit the nation to reducing the emissions intensity of GDP by 45% from 2005 levels, achieving 500 GW of non-fossil fuel capacity by 2030, and moving towards net-zero emissions by 2070 (Sanskriti IAS, 2025; PIB, 2025a). These ambitious targets are not only environmental commitments but also signal an inevitable transformation in India's economic structure. Meeting them requires massive investment in renewable energy, reorientation of industrial processes, reform in transport and urban planning, and alignment of financial systems to green growth pathways. The trajectory is therefore not just about compliance with global climate goals but about reshaping the foundations of India's development model to be future-ready, resilient, and sustainable.

The economic implications of climate inaction are already well documented. Research shows that climate change could reduce India's GDP by 2.6% under a 2°C warming scenario, escalating to a dramatic 13.4% reduction under a 4°C scenario by the end of the century (Kumar & Maiti, 2024; CESS, 2024). This translates into substantial losses for households, businesses, and the state, with cascading impacts on employment, trade competitiveness, and fiscal stability. Studies also estimate that a rise of 1°C in average temperature could shave off 2.5% of India's GDP growth, a figure that highlights the magnitude of the economic risks involved. Agriculture, which supports nearly half of India's population through direct or indirect employment, emerges as one of the most vulnerable sectors, facing threats from changing rainfall patterns, rising temperatures, and extreme weather events (Hilarispublisher, 2019). The vulnerability of agriculture further compounds risks of rural distress, food insecurity, and widening inequalities, which in turn have implications for political stability and social welfare. Against this backdrop, the present study adopts an economic lens to examine India's progress towards SDG 13, with a focus on financial requirements, policy frameworks, institutional implementation, and long-term developmental trade-offs. It seeks to highlight not only the progress achieved so far but also the critical gaps that need urgent attention to ensure that India's climate action is consistent with both its economic aspirations and its global responsibilities.

Literature Review and Theoretical Framework

SDG 13 is structured around five interlinked targets that together define the global agenda for climate action. These include strengthening resilience and adaptive capacity to climate-related hazards, integrating climate measures into national policies and planning, improving education and institutional capacity on climate change, fulfilling climate finance commitments made under the Paris Agreement, and promoting capacity building in developing countries through international cooperation (Wikipedia, 2020; UNDESA, 2025). Despite the global recognition of these priorities, progress remains deeply uneven. Currently, only 17 percent of the global SDG targets are on track for achievement by 2030, highlighting the critical need for increased action. In the case of India, the country's overall SDG ranking improved to 99th position in 2025, reflecting progress in areas such as poverty reduction, health, and education. However, SDG 13 stands out as an area of concern, with the indicators showing a "worsening trend" (Drishti IAS, 2025). This contrast highlights the difficult balance between sustaining development gains and aligning with global climate goals.

The economic theory of climate action offers beneficial explanations for why this imbalance persists. It emphasizes the concept of the social cost of carbon, which captures the economic damages resulting from each additional ton of carbon dioxide emitted into the atmosphere. This framework demonstrates that the cost of inaction is often much greater than the cost of mitigation. The theory also highlights the co-benefits of climate investments, which extend beyond emissions reductions to include public health improvements, reduced energy imports, enhanced energy security, and the creation of new employment opportunities. Energy transition economics further illustrates that moving from fossil fuels to renewables generates long-term savings and stability despite higher upfront costs. India's climate policy has been designed around a co-benefits approach by explicitly aligning climate investments with development priorities such as energy access, job creation, and technological innovation. The Indian context underscores the importance of taking climate action. A panel data analysis of India's states shows that each degree Celsius increase in temperature reduces growth rates by around 2.5 percent, with the effects being especially severe in poorer and agriculture-dependent regions (Kumar & Maiti, 2024). This finding demonstrates how climate change threatens aggregate growth and exacerbates regional disparities, thereby deepening existing socio-economic inequalities.

Climate finance theory offers another critical lens for examining India's climate action pathway. It emphasizes the importance of using public finance to leverage and mobilize private investment through mechanisms such as risk-sharing instruments, blended finance structures, and concessional loans. The scale of resources required is daunting. India's updated NDCs estimate that the country will need about USD 2.5 trillion between 2015 and 2030, averaging close to USD 170 billion per year. Yet the mobilization of finance remains far below this level, as only USD 44 billion was raised in 2021–22 (Climate Policy Initiative, 2024). Looking further ahead, the International Finance Corporation projects that India will require cumulative climate-related investments of nearly USD 10.1 trillion by 2070 to achieve its long-term goals (IFC, 2023). Meeting these requirements will demand the development of innovative financial instruments such as green bonds, expansion of carbon markets, and a stronger role for international climate finance. It will also necessitate deeper domestic reforms in the financial sector to integrate climate risks into lending practices and investment decisions. Without these shifts, India risks facing a widening financing gap that could undermine its ability to achieve both climate resilience and sustained economic development.

Methodology

The study employs a mixed-method approach drawing on both quantitative and qualitative sources. Primary data are obtained from official publications of the Ministry of Environment, Forest and Climate Change (MoEFCC), NITI Aayog, and the Ministry of Statistics and Programme Implementation (MoSPI), supplemented by reports from United Nations agencies, the International Finance Corporation (IFC), the Council on Energy, Environment and Water (CEEW), and relevant academic working papers. The quantitative component examines progress towards India's Nationally Determined Contributions (NDCs), assesses climate finance mobilization in relation to estimated requirements, evaluates macroeconomic and sectoral impacts of climate change, and analyzes indicators of structural transformation. The policy analysis component reviews the evolution of the

National Action Plan on Climate Change (NAPCC), the implementation record of State Action Plans on Climate Change (SAPCCs), and the degree of policy coherence and alignment with the targets of SDG 13.

INDIA'S CLIMATE ACTION PROGRESS: MOVING TOWARDS TARGETS

India's journey in addressing climate change shows notable strides towards fulfilling its SDG 13 commitments, yet it still faces important hurdles in boosting ambition and putting plans into action. The country has already exceeded its initial NDC targets, managing to cut emissions intensity by 33 percent from 2005 to 2019 and beating its 2030 non-fossil fuel capacity goal by 2025, highlighting a promising start in low-carbon transitions. The growth of renewable energy, especially solar, has propelled us to this milestone, with capacity hitting 234 GW by August 2025. However, pesky transmission constraints still hold back our progress. Simultaneously, the economic risks tied to climate change are becoming more and more apparent, with forecasts suggesting significant GDP losses by 2100 and serious effects on agriculture, manufacturing and services. State-level action has become a key player in driving progress, featuring a mix of large-scale renewable energy projects, industrial decarbonization efforts, community-based adaptation strategies and innovative approaches to climate finance. However, these endeavors face limitations due to funding shortfalls, institutional challenges and coordination issues, underscoring the necessity for more profound systemic changes to support India's climate action path. This section takes a closer look at India's accomplishments, the shifts across various sectors, the economic challenges it faces and the initiatives at the state level, all to evaluate how the country is moving towards the targets of SDG 13.

Early NDC Target Achievement

India's progress on its climate commitments has been marked by significant early success in meeting national targets under the Paris Agreement. The country has advanced faster than expected in reducing emissions intensity and expanding non-fossil energy capacity, highlighting strong policy measures and rapid deployment of clean technologies. Table 1.1 highlights India's impressive strides in reaching its Nationally Determined Contribution (NDC) targets, reflecting not just the extent of success but also the speed of progress. The country managed to cut its emissions intensity by 33 percent from 2005 levels by 2019, beating the 2025 target by a whole six years. In a remarkable feat, India reached 43.81 percent of its installed electricity capacity from non-fossil fuel sources by October 2023, surpassing the 2025 deadline by a whole two years. Interestingly, by June 2025, the share of non-fossil fuel capacity hit 50.07 percent, exceeding the 2030 target a whole five years ahead of schedule. These outcomes show a lively push in the clean energy transition and highlight how well India's policy framework is working to speed up low-carbon growth. Yet, even though early successes hint at advancement, keeping up this momentum brings its own set of hurdles. These include the pressing demand for extensive grid expansion, innovative storage solutions, and effective financing strategies to support the swift integration of renewables. The data shows that India is not just on track to meet global commitments ahead of schedule; it also highlights the changing structural and financial needs required to maintain its leadership in climate action.

Table 1.1 – India's Progress on NDC Targets

Target/Indicator	Status Achieved	Target Year	Achievement Year
Emissions intensity reduction (vs. 2005)	33% reduction	2025	2019
Non-fossil fuel electricity capacity	43.81%	2025	Oct-23
Non-fossil fuel electricity capacity	50.07%	2030	Jun-25

Source(s): PIB (2023), PIB (2025a), PIB (2025b)

Renewable Energy Transformation

India's energy transition is being driven by the rapid growth of renewable power, particularly solar. Policy incentives, falling costs, and technological improvements have enabled large-scale adoption, though future expansion will depend on addressing infrastructure and grid integration challenges.

Table 1.2 – Growth Trends in India's Renewable Energy

Indicator	Value Achieved	Year	Notes
Renewable capacity	234 GW	Aug-25	Includes solar, wind, hydro, bio
Capacity added in FY 2024–25	29.52 GW	2025	Mostly solar

Solar tariffs	₹6.17 → ₹2.15 per kWh	2014–2025	Significant tariff decline
Required for 500 GW target	257.2 GW more	2025–2030	Transmission bottlenecks

Sources: EQ International (2025), PIB (2025c), CNBC TV18 (2025)

Table 1.2 highlights the latest trends and challenges facing India's renewable energy sector. By August 2025, the country boasts a total installed renewable capacity of 234 GW, showcasing significant input from solar, wind, hydro and bioenergy, which positions India as one of the fastest-growing clean energy markets in the world. During FY 2024–25, a remarkable 29.52 GW was added, primarily from solar energy, highlighting the pivotal role of photovoltaic power, bolstered by government initiatives and advancements in technology. The growth we've seen is largely due to a significant drop in solar tariffs, plummeting from ₹6.17 per kWh in 2014–15 to just ₹2.15 per kWh in 2024–25, which has made solar power a more appealing option compared to traditional energy sources. Still, India has to add another 257.2 GW by 2030 to hit its ambitious 500 GW goal. This challenge is made trickier by transmission bottlenecks and grid integration hurdles, which call for significant investments and reforms to keep the progress going.

Economic Impacts

Climate change poses significant risks to India's economy, with impacts projected across multiple sectors. Rising temperatures, extreme events and ecosystem stresses are expected to influence growth patterns, agricultural yields and industrial productivity in the long term.

Table 1.3 – Projected Economic Impacts of Climate Change in India

Sector / Indicator	**Projected Impact**	**Scenario/Temp Rise**	**Time Horizon**
GDP loss	-2.60%	+2°C	2100
GDP loss	-13.40%	+4°C	2100
Crop yield loss	-4% to -20%	+1°C	Near–mid term
Manufacturing & services	Productivity decline, infrastructure risks	Climate stress	21st century

Sources: CESS (2024), CEEW (2025), Kumar & Maiti (2024)

Table 1.3 demonstrates the notable economic challenges India encounters due to climate change, with forecasts indicating both broad economic and specific sector weaknesses that clearly emphasize the pressing need for SDG 13. In a scenario where temperatures rise by 2°C, India's GDP might take a hit of about 2.6 percent by the year 2100. If things escalate to a 4°C increase, the losses could soar to around 13.4 percent, highlighting the significant economic consequences of postponing necessary actions. Agriculture, a lifeline for almost half the population, faces significant challenges, with crop yields expected to drop by 4 to 20 percent for every 1°C rise in temperature. This situation poses serious risks to food security, rural livelihoods, and efforts to reduce poverty. Manufacturing and services, the driving forces behind India's growth, face their own set of challenges from heat stress and increasing infrastructure risks, which could lead to ongoing pressures on competitiveness and the ability of urban areas to adapt and thrive. These projections show that making headway on SDG 13 is not just an environmental necessity but also a vital economic shield. Speeding up our efforts in mitigation and adaptation is key to safeguarding growth, stability, and inclusive development in the years to come.

4.4 State-Level Implementation

Climate action at the state and union territory level in India reflects diverse strategies that build on regional strengths and vulnerabilities. While innovative approaches have emerged in several states, effective implementation continues to depend on finance, institutional capacity and coordination mechanisms.

Table 1.4 – Major State-Level Climate Actions in India

State	Key Initiatives	Sectoral Focus
Gujarat	Asia's largest solar park; climate risk insurance for farmers	Energy, Agriculture
Kerala	Post-2018 flood resilience; community-based adaptation	Disaster Risk, Communities
Tamil Nadu	Green industrial clusters; MSME carbon accounting	Industry, MSMEs
Maharashtra	Mumbai Net-Zero 2050; climate bonds for infrastructure	Urban, Finance
Himachal Pradesh	E-vehicles in tourist zones; carbon credit schemes	Transport, Carbon Markets
Cross-State	SAPCC implementation challenges	Funding, capacity, coordination

Sources): NetZero India (2025), Oxford Policy Management (2015)

Table 1.4 showcases the rich tapestry of diversity and innovation in India's state-level climate actions, emphasizing the unique ways subnational governments are pushing forward SDG 13 with tailored strategies that reflect their specific contexts. Gujarat has really made a name for itself in the renewable energy scene, boasting Asia's largest solar park. At the same time, it's been working to ease the worries of farmers by rolling out insurance schemes tailored just for them. Kerala has made disaster resilience and community-based adaptation a top priority, especially following the catastrophic floods of 2018. Meanwhile, Tamil Nadu has woven climate action into its industrial strategy, creating green industrial clusters and requiring carbon accounting for MSMEs. Maharashtra shines with its flair for financial innovation and urban dynamism, highlighted by the Mumbai Net-Zero 2050 commitment backed by climate bonds. In contrast, Himachal Pradesh takes a different path, prioritizing sustainable transport and carbon credit markets that align with its eco-sensitive tourism economy. These states are leading the way in syncing their sectoral policies with climate goals, showcasing how local efforts can play a part in achieving national targets. Yet, a number of other states find themselves held back by a mix of limited resources, shaky institutional capacity and a lack of cohesive coordination, leading to a patchy application of SAPCCs throughout the nation. The difference between energetic leaders and those who take their time showcases the promise of decentralized climate governance while also pointing out the necessity for more robust national systems. These systems can help close gaps, expand successful approaches, and guarantee that progress toward India's SDG 13 commitments remains unified.

ECONOMIC ANALYSIS OF CLIMATE FINANCE REQUIREMENTS

Securing sufficient climate finance is crucial for India as it moves toward a low-carbon, climate-resilient economy, especially considering the substantial investments needed to achieve both mitigation and adaptation objectives. The current state of climate finance is falling short of what's necessary, with projections suggesting that we need about USD 170 billion each year until 2030, and even more ambitious commitments as we move toward the middle of the century. Section - Investment Needs and Gaps, brings attention to the widening investment gaps, showcasing the stark difference between current inflows and the trillions needed for clean energy, adaptation, and resilience efforts in the years ahead. Section - Sectoral Requirements shifts, focus to the specific needs of various sectors, detailing the financing priorities in energy, industry, transport, and adaptation. Here, the emphasis is on large-scale renewable deployment, technologies for industrial decarbonization, electric mobility, and climate-smart agriculture, all of which are set to influence India's climate finance landscape.

Investment Needs and Gaps

Closing the gap between the scale of resources required and the finance currently available is one of the most critical challenges for India's climate transition. While there is broad recognition of the importance of investing in both mitigation and adaptation, the financial ecosystem still falls short in terms of volume, accessibility, and alignment with long-term climate goals. This section examines the overall investment landscape, highlighting the structural financing gaps and the urgent need for innovative approaches that integrate public, private, and international support to advance India's climate ambitions.

Table: 1.5 India's Climate Finance Investment Needs and Current Flows

Category	Estimated Requirement / Flow	Timeline
Annual investment needs	USD 170 billion per year	Until 2030
Total cumulative needs	USD 10.1 – 15.7 trillion	By 2070
Clean energy investment	USD 253 – 263 billion	2026–2030
Clean energy investment	USD 325 – 355 billion	2031–2035
Adaptation investment	USD 1 trillion	By 2030
Current climate finance flow	USD 44 billion per year	Latest estimate

Sources: IFC (2023); CEEW (2025) & Climate Policy Initiative (2024)

Table 5.1 reveals the striking difference between what India needs for climate finance and the financial resources currently available. By 2030, it's estimated that we'll need around USD 170 billion in investments each year, and this figure is expected to climb to more than USD 10 trillion in total by 2070 to stay on track with the net-zero goals. Clean energy is stepping into the spotlight, calling for significant investment not just in the medium term (2026–30) but also in the years to come (2031–35) to support the growth of renewables, improve the grid, and advance storage solutions. Adapting to change comes with a hefty price tag, as a whopping USD 1 trillion is required by 2030 to bolster agriculture, enhance water systems, and improve urban climate resilience. When we look at these numbers, the current annual inflows of about USD 44 billion highlight a notable financing gap, emphasizing the pressing need to rally both domestic and international resources by employing creative strategies and enhancing policy frameworks.

Sectoral Requirements

India's journey towards low-carbon development is influenced by a variety of financing requirements across essential economic sectors. Every sector—from energy and industry to transport and climate adaptation—needs customized investments, technologies, and policy backing to reach significant decarbonization and resilience. This section delves into the unique aspects of finance across different sectors, highlighting how technology, infrastructure and institutional capabilities are all interconnected in a dynamic dance. The emphasis is on grasping how specific sector needs morph into focused investment priorities within the wider climate finance landscape.

Table: 1.6 Sectoral Climate Finance Requirements for India

Sector	Key Requirements / Focus Areas	Timeline
Energy	500 GW renewable capacity	By 2030
	Solar capacity expansion to 5,600 GW	By 2070
	Wind capacity expansion to 140 GW	By 2030
Industry	Decarbonization of steel and cement through hydrogen & CCUS	Ongoing/2030+
Transport	Electric vehicle (EV) charging infrastructure	Ongoing/2030+
	Development of sustainable aviation fuels	Ongoing/2030+
Adaptation	Drought-resilient agriculture strategies	By 2030
	Urban flood management systems	By 2030

Sources: CEEW (2021); PIB (2025c) & IFC (2023)

Table highlights the unique financing needs of various sectors that shape India's journey towards low-carbon development. The energy sector holds the biggest chunk of requirements, aiming high with its goals for expanding renewable capacity, especially in solar and wind power, to achieve significant decarbonization by the middle of the century. At the same time, the industry needs to pour resources into groundbreaking technologies, like green hydrogen and carbon capture, utilization, and storage (CCUS), to tackle emissions from those tough-to-tackle sectors such as steel and cement. The transport sector needs a good chunk of funding to set up EV charging systems and push forward the development of sustainable aviation fuel to make mobility greener. Adapting to our changing world requires us to prioritize funding, emphasizing climate-resilient agriculture and enhancing urban infrastructure to tackle the challenges of droughts and flooding. Collectively, these sectoral requirements reflect the rich variety and breadth of investment priorities that shape India's climate finance landscape.

POLICY FRAMEWORK ANALYSIS

The National Action Plan on Climate Change (NAPCC), introduced in 2008, provides the overarching policy framework for India's climate strategy and is anchored around eight core missions: solar energy, energy efficiency, sustainable agriculture, water resources, sustaining the Himalayan ecosystem, sustainable habitat, the Green India Mission, and strategic knowledge on climate change (DST, 2019). Among these, the National Solar Mission has emerged as a major success, significantly accelerating renewable energy deployment and positioning India as a global leader in solar power. In contrast, other missions have experienced uneven outcomes due to institutional, financial, and coordination constraints. To complement the NAPCC architecture, the government has introduced the National Hydrogen Mission, targeting the production of five million tonnes of green hydrogen annually by 2030 (UNDP, 2025). This signals a shift toward next-generation technologies and a broadening of India's policy focus beyond conventional renewable energy pathways.

The governance of climate action in India involves a multi-layered institutional arrangement led by the Ministry of Environment, Forest and Climate Change (MoEFCC) and NITI Aayog, which jointly oversee the coordination of Sustainable Development Goal 13 (climate action) (NITI Aayog, 2025). However, the federal structure presents inherent challenges in aligning national aspirations with state-level capabilities and priorities. While some states demonstrate strong institutional arrangements and capacity for climate planning, others lag behind due to inadequate resources and expertise (Sami et al., 2017). Moreover, local governments, including municipal bodies and panchayats, remain largely excluded from mainstream climate planning and decision-making (Oxford Policy Management, 2015). These governance asymmetries result in fragmented implementation and highlight the need for stronger vertical and horizontal coordination mechanisms to ensure that climate policies are coherent, inclusive, and effective across all levels of governance.

Over the past decade, climate priorities have been increasingly integrated into India's broader economic and development planning, with financial and regulatory innovations playing an important role in this transition. Instruments such as climate budget tagging, differential Goods and Services Tax (GST) rates for clean technologies, and sovereign green bonds are helping to align fiscal policy with climate goals (IFC, 2023; NITI Aayog, 2025). These efforts represent important steps toward embedding sustainability into the financial system, enhancing transparency, and unlocking new sources of green capital. Nevertheless, the scale of resources required demands further expansion of fiscal space to support both mitigation and adaptation priorities. Ensuring a stronger synergy between economic planning and climate objectives will be critical not only for mobilizing finance at scale but also for fostering private sector participation, advancing technology adoption, and embedding climate resilience into India's long-term growth strategy.

REGIONAL AND STATE-LEVEL VARIATIONS

India's climate vulnerability is deeply shaped by its geography and socio-economic diversity, with different regions exposed to distinct risks. Coastal areas face rising sea levels, cyclones, and saline intrusion, threatening livelihoods and infrastructure; the Himalayan belt is increasingly prone to glacial melting, landslides, and erratic precipitation; while arid and semi-arid regions struggle with water scarcity and desertification. These vulnerabilities are not just ecological but also economic, as climate impacts directly affect productivity, agriculture, and infrastructure reliability. Studies suggest that southern states are particularly exposed, experiencing relatively higher GDP losses per degree of warming due to concentrated urban settlements, dependence on climate-sensitive sectors, and the high economic value of coastal ecosystems (Kumar & Maiti, 2024). Such regional disparities underscore the urgency of locally tailored adaptation strategies within India's broader climate resilience framework.

Responding to these diverse vulnerabilities, Indian states have demonstrated leadership in policy innovation, creating models that combine mitigation and adaptation with local contexts. Gujarat has pioneered large-scale solar energy deployment alongside innovative climate risk insurance products for farmers, while Kerala's post-flood recovery strategy has strengthened resilience through community-driven climate literacy initiatives. Tamil Nadu has advanced low-carbon industrialization by establishing green industrial clusters and promoting carbon accounting practices among micro, small, and medium enterprises (MSMEs). Maharashtra has taken a finance-led approach, issuing climate bonds to mobilize resources for sustainable infrastructure while aligning its goals with the city of Mumbai's net-zero target. Together, these examples reflect the growing experimentation at the state level, where tailored solutions are being developed to bridge policy ambition and ground-level implementation (NetZero India, 2025).

Amid vulnerabilities and sectoral challenges, India's evolving policy landscape also presents new opportunities to leverage climate action for development co-benefits. The 15th Finance Commission has introduced performance-linked incentives for states to invest in climate resilience, embedding climate considerations into fiscal federalism. The National Clean Air Programme provides an important co-benefit framework, where efforts to reduce air pollution simultaneously advance climate mitigation and public health outcomes. Furthermore, emerging domestic carbon markets offer pathways to mobilize private capital, reward low-carbon practices, and integrate India more effectively into global climate finance mechanisms (NITI Aayog, 2025; PIB, 2025a). Harnessing these opportunities requires coordinated institutional efforts, effective monitoring frameworks, and a clear policy environment to encourage long-term investment and innovation.

CHALLENGES AND BARRIERS

One of the most persistent barriers to India's climate transition is the mismatch between the scale of required finance and the level of existing flows. Estimates suggest that India needs approximately USD 170 billion annually to remain on track for its climate and energy targets, yet current flows are closer to USD 44 billion per year (Climate Policy Initiative, 2024). This funding shortfall hampers investments in clean energy, adaptation infrastructure, and green technologies. Institutional innovations such as a national climate bank and mechanisms for de-risking private investment are considered critical to mobilize capital at scale (IFC, 2023). Without such instruments, high upfront costs and perceived market risks will continue to deter investors, slowing the pace of low-carbon transformation.

Alongside financial constraints, India's climate agenda also faces considerable policy-related challenges. The federal structure of governance often results in coordination gaps across central, state, and local levels, contributing to fragmented implementation (Sami et al., 2017). Moreover, capacity constraints within state agencies and local institutions limit their ability to design and enforce effective climate policies. Regulatory uncertainties, combined with delays in updating sectoral frameworks, create barriers for private participation and the adoption of emerging technologies. In addition, the broader political economy of energy transition—shaped by legacy dependence on coal, entrenched interests, and trade-offs with developmental priorities—further complicates the policy environment (NITI Aayog, 2025). These dynamics make it difficult to balance immediate developmental needs with the long-term imperatives of climate resilience and decarbonization.

The realization of India's climate targets is also hindered by significant technical and infrastructural barriers. The rapid addition of renewable generation capacity is constrained by grid integration challenges and the high costs of large-scale energy storage solutions (PIB, 2025c). Supply chain dependence on imported solar modules, batteries, and critical minerals continues to expose vulnerabilities, while workforce shortages and skill gaps limit the speed of deployment. Further, research and development (R&D) spending in clean technologies remains relatively low compared to the scale of technological ambition (CEEW, 2025). Addressing these challenges requires coordinated investment in grid modernization, domestic manufacturing ecosystems, skill development programs, and a stronger innovation pipeline to ensure that India's climate transition is both sustainable and resilient.

OPPORTUNITIES AND RECOMMENDATIONS

India's low-carbon transition is not only a necessity but also an opportunity to drive new forms of economic growth. The country's strategic push for green hydrogen has the potential to position it as a global exporter, particularly to industrialized economies seeking clean energy imports. Expanding domestic capacity in renewable energy manufacturing—including solar modules, wind turbines, and energy storage technologies—can reduce import dependence while creating jobs and fostering industrial competitiveness. At the same time, the development of carbon credit markets offers the possibility of mobilizing private finance and incentivizing emissions reductions across sectors. Furthermore, advancing a circular economy framework that promotes recycling, material efficiency, and resource recovery presents an integrated approach to growth that combines environmental sustainability with industrial productivity (CEEW, 2025).

Accelerating India's climate transition will require robust policy instruments that strengthen institutions, improve market signals, and ensure a socially equitable pathway. First, innovations in the climate finance architecture—such as establishing a national climate investment bank and empowering state-level green finance agencies—can help mobilize and channel resources at scale (IFC, 2023). Second, implementing carbon pricing mechanisms, including emissions trading schemes and revenue recycling, can provide effective market incentives while ensuring equitable resource allocation. A just transition framework is crucial for managing disruptions in fossil fuel–dependent regions, where retraining programs, social protection systems, and community development efforts will be key. Finally, mainstreaming climate action into governance through climate budget tagging, mandatory impact assessments, and evidence-based planning will ensure that climate considerations are fully embedded within India's economic and developmental frameworks (IFC, 2023; NITI Aayog, 2025).

India's ability to achieve its climate goals will also depend significantly on strengthening international partnerships. Enhanced South–South cooperation can foster technology exchange, capacity building, and best-practice sharing among developing economies facing similar challenges. At the same time, active engagement in North–South cooperation remains vital for accessing advanced technologies, concessional finance, and capacity support. India's leadership in international platforms such as the International Solar Alliance (ISA) and Mission Innovation further underscores its role as a global convenor in driving clean energy deployment. However, greater alignment of trade policy with climate objectives will be necessary to ensure that global supply chains and market access reinforce, rather than hinder, decarbonization goals. Together, these efforts can position India not only as a climate leader in the Global South but also as a key architect of global climate governance (UNDP, 2025).

Conclusion

India's climate journey showcases the vastness of the challenge ahead, along with the exciting opportunities that arise from taking bold steps forward. The country has really stepped up by pushing forward with renewable energy, hitting its emission reduction targets earlier than expected, and carving out a role as a key player in the global climate conversation. Meanwhile, the ongoing financing gaps, policy hurdles, and technical limitations serve as a reminder that progress can be unpredictable and isn't always assured. Climate change brings along considerable challenges for economic growth, ecosystems, and human wellbeing, yet it also opens up opportunities for innovation, the rise of green industries, and fresh avenues for international cooperation. To turn ambition into enduring results, India must rally financial resources on a grand scale, invest in robust infrastructure, and make sure that governance systems work together smoothly at national, state, and local levels. It's also crucial to understand that climate action and development aren't at odds with each other; instead, they actually support and enhance one another in meaningful ways. By weaving climate considerations into economic strategies, uplifting vulnerable communities through a fair transition, and tapping into new markets and technologies, India can carve out a route that brings together sustainability and prosperity. The path ahead for India’s climate action is all about seizing this unique chance—caring for our planet while nurturing growth that includes everyone and stands strong against challenges.

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5.

DELIVERING LIVELIHOODS: A SOCIO-ECONOMIC STATUS OF GIG DELIVERY WORKERS IN KERALA

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Abstract

This study examines the socio-economic conditions of gig workers in Kerala, focusing specifically on delivery personnel employed by major e-commerce platforms such as Flipkart, Amazon, Meesho, and Myntra. As gig work becomes an increasingly prominent mode of employment in India, especially among the youth, this research investigates the income patterns, educational background, consumption behavior, and working conditions of these workers. Primary data were collected from 100 delivery workers aged between 20 and 30 in Kozhikode district, supplemented by secondary sources including government reports and academic literature. Findings reveal that a significant portion of gig workers are highly educated, with many holding degrees or technical qualifications. Despite their qualifications, these individuals earn modest wages, typically based on a per-delivery commission system averaging ₹16 per item. Monthly earnings range between ₹20,000 and ₹28,000, from which expenses such as fuel, communication, and maintenance are deducted. The study highlights the absence of social security benefits, fixed working hours, and job stability in the gig economy. Notably, there is no evident gender-based wage disparity among delivery workers. The paper concludes by recommending policy interventions focused on regulation, skill development, and welfare support to enhance the economic resilience and job quality of gig workers in Kerala.

Keywords: *Gig economy; delivery personnel; platform workers; informal labor; youth employment; socio-economic conditions; Kerala labor market; digital platforms; wage structure.*

1. Introduction

In recent years, the global labor market has undergone a significant transformation with the rise of the gig economy, characterized by short-term, flexible, and task-based employment mediated through digital platforms. Unlike conventional employment, gig work involves independent contractors who are compensated per task, delivery, or service rendered rather than receiving a fixed salary or employment benefits (Kalleberg & Dunn, 2016). This shift has been fueled by technological advances, smartphone penetration, and changing economic behaviors, particularly among youth seeking flexible income sources in rapidly evolving job markets.

India, home to one of the largest labor forces in the world, has witnessed a remarkable expansion of the gig economy, especially in urban and semi-urban regions. With platforms like Uber, Swiggy, Zomato, Amazon, and Flipkart leading the way, gig work has become an alternative—albeit insecure—form of employment for a growing segment of the population (NITI Aayog, 2022). Kerala, known for its high literacy rates and favorable human development indicators, presents a unique case. Despite educational advancement, many of Kerala's youth remain unemployed or underemployed, leading them to take up roles traditionally considered low-skill or temporary, such as delivery work in the gig sector (George & Joseph, 2020).

This study focuses on a distinct category of gig workers in Kerala: delivery personnel working with major e-commerce platforms such as Flipkart, Amazon, Meesho, and Myntra. These individuals are responsible for transporting lightweight parcels—usually under 2 kilograms—from regional company hubs to customer residences, using personal vehicles and digital tools for navigation and communication. Most are paid per delivery, typically around ₹16 per item, and must cover their own operational costs including fuel, mobile data, and vehicle maintenance.

While gig work offers quick employment and flexibility, it also raises concerns about job precarity, insufficient wages, and the lack of formal labor protections. Workers in this sector generally do not receive health insurance, paid leave, or retirement benefits. Furthermore, their workdays are long—often from 9 a.m. to 9 p.m.—and physically demanding, with minimal job security or upward mobility. Many of these workers are educated, with qualifications ranging from higher secondary to technical degrees, highlighting a mismatch between educational attainment and employment quality (Rani & Dey, 2017).

The socio-economic implications of this employment trend are critical. It reflects a structural challenge in the labor market where educated individuals are driven toward informal, insecure work due to limited alternatives. It also raises questions about sustainability, mental well-being, and long-term career prospects for the youth population in Kerala.

Through primary data collected from 100 delivery personnel in Kozhikode district and supported by secondary research, this study seeks to understand the income-consumption dynamics, working conditions, gender representation, and digital dependency among gig workers. The ultimate aim is to contribute to a more informed policy framework that addresses the vulnerabilities of gig workers while acknowledging their crucial role in the digital and consumer economy.

2. Statement of the Problem

Despite Kerala's reputation for high literacy rates, strong social development indicators, and a highly educated youth population, a growing number of young individuals are turning to informal gig work due to a lack of stable employment opportunities in the formal sector. Delivery-based gig jobs, particularly in the e-commerce sector, have become a common fallback option for educated youth seeking income. However, these roles often come with irregular wages, long working hours, absence of job security, and no access to social benefits. The mismatch between educational attainment and the quality of employment raises critical concerns about underemployment, financial vulnerability, and long-term career stagnation. This study seeks to address this disconnect by examining the socio-economic conditions of gig workers in Kerala, focusing on their income, consumption patterns, working environment, and gender dynamics, with the aim of identifying systemic challenges and proposing viable solutions for improvement.

3. Objectives of the Study

1. To examine the income and consumption patterns of delivery personnel working under gig arrangements.

2. To suggest actionable recommendations for improving the socio-economic conditions of gig workers.

4. Methodology

The present study adopts a mixed-method approach, relying primarily on quantitative data supported by qualitative insights to examine the socio-economic conditions of gig workers in Kerala. The research is based on primary data collected through structured interviews and surveys conducted among 100 gig workers employed as delivery personnel in the Kozhikode district. These respondents were selected using a simple random sampling method to ensure unbiased representation across different parts of the district. The participants were between the ages of 20 and 30 and possessed varying levels of education, ranging from higher secondary qualifications to postgraduate and technical degrees.

In addition to primary data, secondary sources were consulted to contextualize the findings and support analysis. These sources include academic journals, government publications, newspaper articles, and previously published studies on the gig economy and labor market trends in Kerala and India more broadly. The tools used for data analysis include statistical techniques such as averages and percentages, as well as graphical methods including bar diagrams, pie charts, and tables to present the data clearly and effectively. This methodological framework enables a comprehensive understanding of income patterns, consumption behavior, work conditions, and other socio-economic indicators relevant to the gig workforce in the selected region.

5. Analysis and Interpretation

This section presents the analysis of primary data collected from 100 gig workers in Kozhikode district, Kerala. The analysis utilizes descriptive statistics and tabular representations to highlight key indicators such as educational qualifications, wage distribution, expenditure patterns, gender participation, and working conditions.

5.1. Educational Background of Gig Workers

Table 1 presents the educational qualifications of the gig workers surveyed. It reveals that a significant portion of them is well-educated, indicating a trend of educated underemployment in the gig economy.

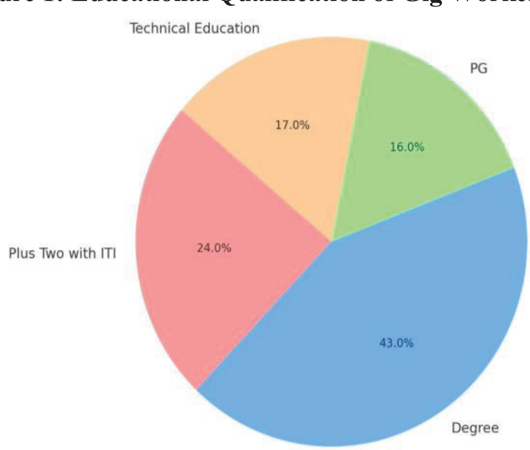
Table 1: Educational Qualification of Gig Workers

Sl. No	Educational Qualification	No. of Employees	Percentage
1	Plus Two with ITI	24	24%
2	Degree	43	43%
3	PG	16	16%
4	Technical Education (e.g. B.Tech)	17	17%
Total		100	100%

Source: Primary Data

Over 76% of gig workers hold a degree or higher qualification, highlighting a disconnect between formal education and gainful employment in Kerala.

Figure 1: Educational Qualification of Gig Workers in Kerala



The figure represents the distribution of workers across four education categories, with the highest share being graduates (43%).

5.2. Consumption Pattern of Gig Workers

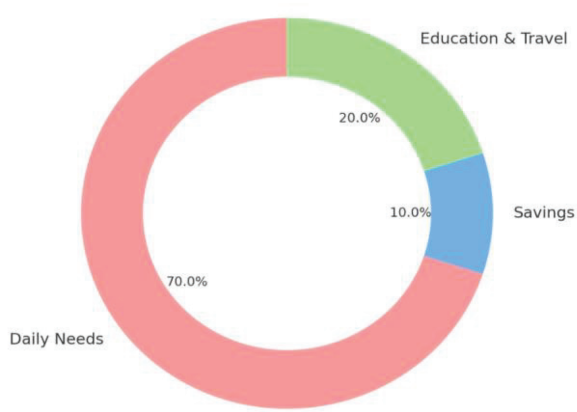
Table 2: Monthly Expenditure Breakdown of Gig Workers

Sl. No	Purpose	Wage Distribution /month	Percentage (%)
1	Daily Needs	10500	70%
2	Savings	1500	10%
3	Education and Travelling Expenses	3000	20%
Total		15000	100%

Source: Primary Data

The majority of income is spent on essential living expenses, leaving little room for savings or personal development. This suggests economic vulnerability and minimal financial cushion among gig workers.

Figure 2: Monthly Expenditure Breakdown of Gig Workers



It clearly shows that 70% of income goes toward daily needs, followed by 20% for education and travel, and only 10% for savings.

5.3. Wage Structure and Daily Earnings

Delivery workers are paid ₹16 per delivery. Based on the number of deliveries (50–70 per day), the daily wage ranges from ₹800 to ₹1120, depending on volume. With an average of 25 working days per month, monthly income typically ranges from ₹20,000 to ₹28,000. However, this is gross income, and net income is lower once fuel, mobile data, and vehicle maintenance are deducted.

5.4. Gender-wise Wage Distribution

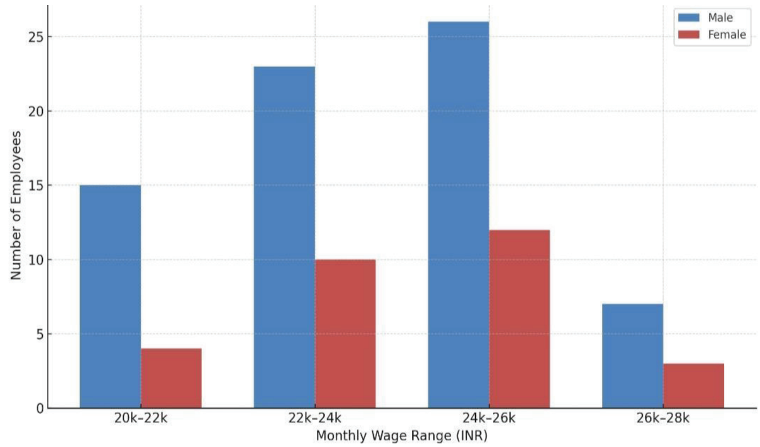
Table 3: Monthly Wages of Gig Workers by Gender

Wage Range	No. of Employees		Average Wage
	Male	Female	
20000 - 22000	15	4	21000
22000 - 24000	23	10	23000
24000 - 26000	26	12	25000
26000 - 28000	7	3	27000
Total	71	29	
	100		

Source: Primary Data

While male workers dominate in numbers, female participation is increasing. There is no evidence of gender-based wage discrimination, suggesting wage equity within this gig sector.

Figure 3: Monthly Wages of Gig Workers by Gender



It highlights gender participation across different earning brackets, showing a relatively consistent presence of female workers alongside males, with no significant wage gap.

5.5. Working Hours and Conditions

Most gig workers reported working from 9 a.m. to 8–9 p.m., totaling 10–12 hours per day. Despite nominal flexibility, the time-intensive nature of deliveries, along with external factors like traffic and customer availability, often leads to extended working hours. Workers use their own scooters and smartphones for operations, bearing full responsibility for fuel, maintenance, and communication expenses. Gig workers experience long working hours, with limited leisure or rest. Their working model is high-output, low-security, and physically demanding.

5.6. Role in the Digital Economy

Gig workers serve as essential links in the digital commerce value chain. By bridging the gap between producers and consumers, they enable the efficient flow of goods in the digital economy. Their services ensure:

Speedy delivery of online purchases,

Reduction in logistical costs for firms,

Convenience for consumers, and

Enhanced consumer satisfaction and retention.

6. Recommendations for Improving the Socio-Economic Conditions of Gig Workers

Based on the analysis of income patterns, work conditions, and expenditure behaviors among gig workers in Kerala, particularly delivery personnel, several challenges have emerged. These include limited income security, absence of social protection, long working hours, and lack of structured support from the platforms they serve. The following are specific, actionable recommendations to address these issues and enhance the socio-economic stability of gig workers:

6.1. Introduce Social Security and Welfare Schemes: The government should establish dedicated welfare boards for gig and platform workers, similar to existing schemes for traditional unorganized sector laborers. These should cover:

Health insurance

Accident and disability coverage

Retirement/pension benefits

Paid sick leave provisions

This can be administered jointly by the state government and platform companies, with mandatory contributions.

6.2. Ensure Minimum Wage and Transparent Pay Structure: Platforms should be regulated to ensure that:

A minimum daily wage or minimum delivery payout is guaranteed.

Pay structures are transparent, with clear communication about incentives, bonuses, and deductions.

Workers are compensated fairly for fuel and vehicle maintenance.

6.3. Limit Overwork and Ensure Rest Breaks: To improve well-being, platforms should:

Introduce maximum working hour caps (e.g., 8–10 hours/day).

Provide structured break periods and support during peak demand periods.

Use app-based alerts to discourage continuous long shifts without rest.

6.4. Offer Skill Development and Career Mobility: Government and private partnerships can offer:

Training in digital literacy, customer handling, vehicle maintenance, and basic finance.

Access to vocational training and upskilling programs for transition into better-paying or more secure roles.

This ensures that gig work is not a long-term trap but a stepping stone toward better employment.

6.5. Formalize Worker Status through Legislation: Kerala can take the lead in:

Recognizing gig workers as a distinct category of labor under labor laws.

Ensuring they receive legal protections and the right to bargain collectively or seek redress through a formal system.

6.6. Promote Platform Accountability: Gig platforms should be made accountable through:

Regular audits of worker conditions

Grievance redressal mechanisms

Worker feedback and representation panels

6.7. Encourage Financial Inclusion: Workers should be supported through:

Access to micro-credit, insurance schemes, and low-interest loans for vehicle maintenance or emergencies.

Training on budgeting, savings, and financial planning.

7. Conclusion

This study has shed light on the evolving socio-economic landscape of Kerala's workforce through the lens of gig workers employed as delivery personnel. Despite being educated and digitally literate, many young individuals in the state are increasingly compelled to take up gig work due to a shortage of stable, formal employment opportunities. The data reveal that a large percentage of gig workers are graduates or technically qualified, yet their earnings remain modest, fluctuating between ₹20,000 and ₹28,000 per month. These earnings are further strained by self-financed work expenses such as fuel, mobile data, and vehicle maintenance.

While gig work offers certain advantages like flexibility and immediate income, it is often accompanied by long working hours, absence of social security, and minimal legal protections. The lack of job benefits, combined with the informal nature of the work, places gig workers in a vulnerable position both economically and socially. However, the sector also shows potential-particularly in its gender wage equity and increasing integration with the digital economy. To build a more equitable and resilient labor system, it is imperative that policymakers, platform companies, and civil society come together to introduce structural reforms. These should include social protection schemes, transparent wage practices, skill development opportunities, and formal recognition of gig workers under labor laws. Only through such integrated efforts can the gig economy evolve into a sustainable and dignified form of employment for Kerala's youth.

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6.

CLIMATE CHANGE, MITIGATION AND ADAPTATION IN AGRICULTURE OF JHARKHAND: A GEOGRAPHICAL ANALYSIS

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Abstract

Global perceptions of climate change are changing both long-term and short-term weather patterns. These shifts not only impact ecosystems and biodiversity but also present major difficulties for agriculture, water supply and human health. As communities adapt to these changes, it becomes crucial to implement sustainable practices that mitigate further environmental damage. Extreme weather conditions vexed the society. Agricultural crops are dependent on climate for their growth. Therefore, current climate change primarily affects the agriculture sector of our economy. The objective of this research paper is to identify the risks affecting agriculture in Jharkhand based on an analysis of secondary data and to suggest pragmatic measures for mitigating the risks of climate change through appropriate adaptation practices, techniques, and skills.

Keywords: *Climate change, Agriculture, Risk, Mitigation, Adaptation*

Introduction

Agriculture is a primary activity of humankind, forming the base of civilization, providing food, and shaping lifestyles. Climate, being the most potent physical force on the earth's surface, governs not only physical phenomena but also influences human socio-economic activities, as humans are the most intellectual organisms on earth. According to noted climatologist Critchfield, just as climate largely defines the global pattern of weather, it also sets the limits for the production of crops and forage, which serve as the primary foundation of today's world food supplies. Thus, climate fundamentally determines agricultural productivity and food security worldwide.

Climate change is one of the biggest challenges faced by the hanuman race today. Unlike changes in the geologic past, which were natural variations, modern climate change is dominated by human influences that are sufficiently large that they exceed the bounds of natural variability. The IPCC has estimated the level of threat to life and socio-economic well-being associated with each degree increase in the global mean temperature. Climate change will severely impact India and Jharkhand. Agriculture, forests, water resources, and human health are expected to be the most impacted sectors due to shifts in precipitation and changes in average minimum and maximum temperatures in specific regions. Furthermore, various climate change models advocated that the that the short-term impacts of ate change will be fresh water availability, food security, energy security, biodiversity, and human health.

Preparation for climate change, which requires a long-term and persistent effort, will be necessary on both mitigation and adaptation fronts. Reducing GHG emissions is a primary necessity for controlling global warming, which is the key driver of climate change. The developed countries bear the primary responsibility for the international mitigation obligation, which centers on reducing their emissions. India is by mitigation commitments but has taken a proactive stance by introducing a voluntary plan to achieve a zero-carbon footprint by 2070, a forward-looking adaptation plan for the country. NAPCC, the National Action Plan for Climate Change, and national adaptation strategies are guided by eight national missions. The NAPCC also establishes the framework for developing a state climate change action plan.

Jharkhand envisioned a climate change action plan aimed at ‘achieving economic growth, poverty alleviation objectives, and enhancing livelihood opportunities while maintaining environmental sustainability.’ In May 2011, the government of Jharkhand initiated the action plan as part of the development process by forming the State Steering Committee and State Advisory Group, with support from UNDP. In the ambience of normative goals, the government of Jharkhand has acted under an action plan for the development process, which included the development of sectoral papers identifying issues and constraints. It developed climate change responses specific to each of the sectors. The responses were on both mitigation and adaptation measures that were shared with department heads on 28th January 2013; further, the plan was open for public comments.

The action plan for Jharkhand's climate change strategy comprises three key segments: First, it sets the background for climate change by describing national-level actions and quantifying climate impacts on the state over short, medium, and long-term durations, establishing the urgency for adaptive measures. Second, it quantifies the impact of climate change on various sectors including agriculture, forestry, industry, mining, power, water, transportation, and human health, detailing the necessary actions to build capacity and successfully address the emerging climate challenges in each sector. Third, the plan outlines the resources required and specifies the timeframe for implementing these state-level climate actions to ensure effective adaptation and mitigation efforts.

Impacts of climate change are already recorded in the state. Changes in weather pattern are reflected in the data recorded by the weather stations of the state. The changes in precipitation and temperature will reflect in economic performance of various sectors. The experiments suggests that agricultural productivity will decrease in the state as the temperature rises. Also, the incidences of pests' growth and other crop diseases will be on rise. Since the most of the agricultural crops in the state under rain-fed harvests. So, their production will go down over time, in the absence of proper irrigation infrastructure.

Objectives of the Study

The objectives of the study are to evaluate the risks and vulnerabilities of climate change on Jharkhand's agriculture, analyze the impacts of changing temperature and rainfall patterns on crop productivity and livelihoods, and assess farmer perceptions of climate variability. Further, the study aims to identify effective mitigation and adaptation strategies, including policy frameworks and sustainable agricultural practices, to enhance resilience in Jharkhand's agro-climatic zones, ensuring food security and socio-economic stability for the predominantly rain-fed and vulnerable farming communities.

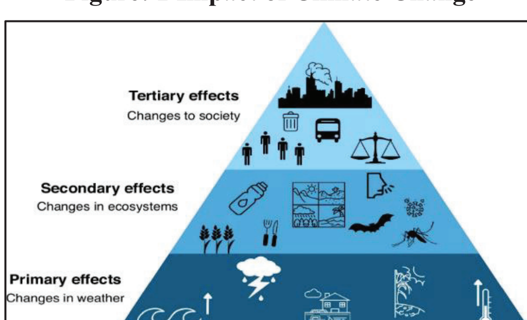
Research Methodology

The research methodology for this study employs a descriptive and analytical approach based on secondary data sources, including climate records from the India Meteorological Department, agricultural productivity reports, government policy documents such as Jharkhand's Climate Change Action Plan and the National Action Plan on Climate Change and farmer perception surveys. The study analyzes long-term temperature and rainfall trends, spatial vulnerability across Jharkhand's agro-climatic zones, and quantifies climate risks to key crops using existing agronomic research. It integrates policy review and synthesis of adaptation and mitigation strategies relevant to Jharkhand's agricultural context. This method enables a comprehensive geographical analysis of climate change impacts, risks, and practical resilience-building measures for agriculture in the state, while acknowledging limitations due to reliance on secondary data and reported studies.

IMPACT OF CLIMATE CHANGE ON JHARKHAND

Climate change refers to long-term shifts in temperature and weather patterns in a region. In Jharkhand, these changes are becoming increasingly evident with rising temperatures and altered rainfall causing more frequent extreme weather events. This disrupts agriculture, water availability, forests, and the livelihoods of its predominantly tribal communities. The state's dependence on rain-fed agriculture and natural resources makes it particularly vulnerable, affecting crop yields, increasing pest infestations, and intensifying water stress. These impacts threaten both the environment and the socio-economic well-being of Jharkhand's people, underscoring the urgent need for adaptive and resilient strategies. (Figure: 1)

Figure: 1 Impact of Climate Change



Source: https://www.nature.com/articles/s41390-024-03153-z/figures/1

Climate change threatens people with increased flooding, extreme heat events, worse food and water scarcity, more diseases, and economic loss, resulting in human migration and conflict. Jharkhand has witnessed large-scale migration in recent decades, national and even international. Present-day climate change includes both global warming—the ongoing increase in global average temperature—and its wider effects on Earth's climate system. Human activities, particularly the burning of fossil fuels since the Industrial Revolution, are driving the current increase in global temperatures. Several independent datasets demonstrate a global rise in surface temperature, with an average increase of 0.20°C per decade. The 2014-2023 decade warmed to an average of 1.190°C compared to the pre-industrial baseline (1850-1900). Not a single year was warmer than the last; internal climate variability processes can make any year 0.20°C warmer or colder than the average.

Many climate change impacts have been observed in the first decade of the 21st century, with 2024 the warmest on record at +1.600°C since regular tracking began in 1850. Under the 2015 Paris Agreement, nations collectively agreed to keep warming "well under 2°C" in the present century. However, with pledges made under the agreement, global warming would still reach about 2.8°C by the end of the century. Limiting warming to 1.50°C requires halving emissions by 2030 and reaching net zero emissions by 2050. Current GHG emission by human activities is the main responsible cause for climate change apart from natural roots. The IPCC (Intergovernmental Panel on Climate Change) has predicted future climate change based on CO_2, which is the most active GHG to cause global warming that led to the climate change scenario concentration model. The Indian subcontinent has witnessed the annual mean minimum temperature rise by 0.270°C during 1901-2007. However, in the recent decade 1998-2007, the maximum temperature showed stagnation in trend. Although, the future prediction shows that the mean winter temperature in the country will increase by as much as 3.20°C by 2050 and 4.50°C by 2080.

Extreme temperature and heat spells have already come over North India. Like precipitation, which is highly dependent on temperature, will also change. It's predicted that the rainfall in most parts of the country will rise significantly in coming years. The Indian Meteorological Department (IMD) observed temperature trends for 35 years, over the period between 1981 and 2015. The IMD evolved spatial maps of the mean temperature over the subcontinent and the linear trend of annual temperature, respectively. Over the past 35 years, Jharkhand's annual mean temperature has been between 24ºC and 26ºC. Furthermore, the warming trends of about 0.4ºCto 0.6ºCare evident in the state over the past 35 years.

Mean temperatures for different seasons (a) Winter (Dec–Jan–Feb), b) Pre-Monsoon (Mar–Apr–May), c) Monsoon (Jun–Jul–Aug–Sep), and d) Post-Monsoon (Oct–Nov) during the period between 1981 and 2015 were also analyzed by the IMD. The maximum warming trends over the 35-year period are most evident in the pre- and post-monsoon seasons. In Jharkhand, for example, the warming trend over the 35-year period has been about 1ºC throughout the pre-monsoon season. In the months following the monsoon, the warming trend has been about 0.5ºC.

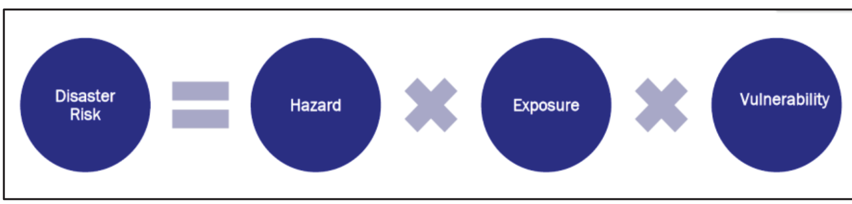
A study conducted on the spatial variability and climate extremes in Jharkhand between 1984 and 2014 revealed a clear warming trend characterized by an increasing number of summer days, rising maximum temperatures, and heightened solar radiation. Concurrently, the region has experienced a decline in rainfall, leading to extended consecutive dry days during the monsoon season. These climatic shifts have disrupted agricultural cycles, causing delays in the transplanting and vegetative phases, which in turn have reduced crop production. Furthermore, there has been a notable increase in the frequency of heat waves, with recorded instances rising from 29 in 2004 to 100 in 2010, highlighting the growing challenge that climate extremes pose to the state's environment and agriculture.

The decadal distribution of rainfall in Jharkhand from 1956 to 2008 shows an overall rise, followed by a sharp decline during 2001–2008, with an average rainfall of 1357 mm in this period. The decade from 1991 to 2000 experienced the highest average rainfall of 1623 mm. Analysis of monthly rainfall variability reveals that the Northeast monsoon (October to November), winter (January to February), and summer (March to May) seasons exhibit greater variability compared to the Southwest monsoon. Despite receiving significant annual precipitation of about 10 million hectare-meters, roughly 20% of rainfall is lost due to atmospheric evaporation, 50% flows away as surface runoff, and only 30% infiltrates into the soil and groundwater. Limited water storage infrastructure and poor natural groundwater recharge result in insufficient surface and groundwater availability, especially for agriculture, thereby posing a challenge to sustainable water management in the state [SAP2014Jharkhand].

Risk and Vulnerability of climate change in Agriculture of Jharkhand

Climate risk is the potential for problems for societies or ecosystems from impacts of climate change. Disaster risk is expressed as the likelihood of loss of life, injury, or destruction and damage from a disaster in a given period of time. Climate risk refers to the potential financial, social, and environmental damage resulting from climate change, which ranges from acute hazards like extreme weather events to gradual changes such as rising sea levels at transition risk. (Committee on Banking Supervision 2021; European Banking Authority EBA 2021.)

Figure: 2 Disaster Risk Equation: Disaster Risk as a Product of Hazard, Exposure, and Vulnerability



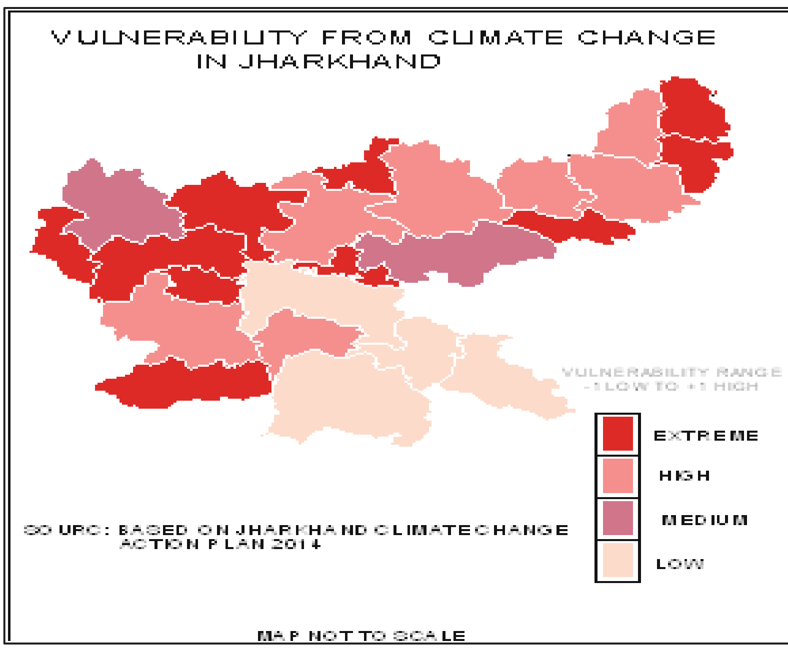
Source: WHO Guidance on Research Methods for Health Emergency and Disaster Risk Management (Saulnier et al., 2018)

Climate change is widely recognized as a major risk to both societies and natural ecosystems, yet the more severe end of this risk spectrum—where the risks become existential—is poorly defined and analyzed in scientific literature. Existential risks threaten the very existence of a subject, which could range from an individual person to an entire community, a nation state, or even humankind as a whole, thus covering impacts at multiple scales from local to global. To clarify the concept of existential risks related to climate change, three levels of severity are proposed: (1) physical threats to human life; (2) threats to basic human needs such as water, food, health, and shelter; and (3) conditions or risks that undermine the foundations of living standards necessary for acceptable well-being. These levels together help specify the scope of climate-related existential threats and highlight the varying degrees of impact they can have on individuals and societies.

Vulnerability from Climate Change in Jharkhand

Climate change impacts are not distributed evenly across Jharkhand; this map illustrates the varying degrees of vulnerability among districts, ranging from low to extreme. Areas categorized as "extreme" vulnerability face the greatest risks from climate-induced factors such as erratic rainfall, rising temperatures, and water stress, while other districts fall under high, medium, or low vulnerability. Understanding this spatial variation is crucial for targeted adaptation and resilience-building efforts in the state.

Map: 1 Risk of Climate Change in Jharkhand



Source: Jharkhand Climate Change Action Plan 2014

The characteristics of vulnerability determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards. Exposure makes risks.

Risk on Agriculture Sector of Jharkhand

Agriculture is the main livelihood option and one of the primary sources of people's household self-consumption and income in rural and peri-urban areas of low- and middle-income countries. Nevertheless, this activity is highly sensitive to changes in temperature and precipitation regimes. Due to observed changes in climate, almost every aspect of food security (i.e., production, access, and price stability) has been affected, especially in poor and vulnerable societies. Such a situation puts agricultural livelihoods at risk and in a state of insecurity, threatens food production at the local level, and can lead to cascade impacts on regional and global populations.

Agriculture is the primary livelihood for approximately 76% of Jharkhand's population, practiced under a tropical monsoon climate characterized by high unpredictability. It largely occurs on the rolling plains of the stepped plateau regions known as tanr and don. Major crops include cereals such as paddy, wheat, maize, ragi, and bajra; oilseeds like mustard, linseed, sesame, and groundnut; and pulses including gram, lentil, peas, arhar, and kulthi. Jharkhand is divided into three agro-climatic sub-zones each with distinct conditions: the Central North Eastern Plateau with low soil water retention, erratic monsoon patterns, and water storage challenges affecting Rabi crops; the Western Plateau facing similar monsoon variability and poor soil-water conservation; and the South Eastern Plateau marked by uneven rainfall, eroded soils, and poor fertility. The state's agricultural economy is heavily reliant on natural conditions, characterized by low investment, low productivity, predominance of mono-cropping mainly paddy, inadequate irrigation, and predominance of small and marginal landholdings. Of Jharkhand's total 79.414 lakh hectares, only 25 lakh hectares are net sown area while 38 lakh hectares are cultivable. Paddy remains the dominant crop, wholly dependent on monsoon rainfall, making the agriculture sector highly vulnerable to climate variability and water insecurity.

Climate Change & Agriculture in Jharkhand

Climate change significantly affects crop production and productivity in Jharkhand, with temperature rise being the primary driver of agricultural vulnerability. Research indicates that for every 1°C increase in temperature, yields of major crops including rice, wheat, soybean, mustard, groundnut, and potato are expected to decline by 3-7% (Global Agriculture, 2023). Paddy, the dominant crop cultivated on approximately 70% of the kharif area, experiences an estimated 18% yield loss with a 2°C temperature increase when CO_2 levels remain constant at 380 ppm (NABARD, 2018). Wheat production faces similar challenges, with a 0.5°C increase in winter temperature reducing crop duration by seven days and causing a 10% reduction in production (Government of Jharkhand, 2014). Temperature stress has been observed to advance flowering by 12 days and shorten the growing period by 7-8 days in wheat varieties, leading to considerable yield reductions from 43.6 to 30.3 quintals per hectare in some cases (Wadood &

Kumari, 2011). Maize cultivation also suffers from elevated temperatures, with yields declining when mean air temperature increases by 3°C above current ambient conditions, while mustard shows a 20.9% yield reduction with a 5°C temperature rise (NABARD, 2018).

The state's agriculture sector, characterized by 92% unirrigated land and heavy dependence on monsoon rainfall, faces additional challenges from erratic precipitation patterns and extreme weather events (NABARD, 2018). Climate variability has led to a shift from diverse multi-cropping systems to intensive mono-cropping of paddy, reducing agricultural diversity and increasing vulnerability to climate shocks (Ghosh-Jerath et al., 2020). The tribal farming communities, particularly the Sauria Paharia, report reduced productivity of indigenous crop varieties, including cowpea, pearl millet, and red gram, due to insufficient and erratic rainfall patterns (Ghosh-Jerath et al., 2020). Extreme weather events, including 100 heat wave incidences recorded in 2010 with temperatures reaching 46.5°C, further compound agricultural stress (Government of Jharkhand, 2014). While increased atmospheric CO_2 concentrations may provide some positive effects—such as a potential 16.27% yield increase in paddy with CO_2 levels rising to 400 ppm—these benefits are often offset by the more dominant negative impacts of rising temperatures (NABARD, 2018). The cumulative effect of these climate-induced changes threatens the livelihoods of approximately 76% of Jharkhand's population dependent on agriculture, necessitating urgent adaptation and mitigation strategies.

Farmer Views on Climate Change in Ranchi

The perceptions of farmers in Ranchi reveal significant awareness of the impacts of long-term climate change on agriculture. Farmers in Ranchi show strong awareness of long-term climate change impacts on agriculture. Nearly half report decreased Kharif crop area, and over 82% note reduced use of traditional varieties, hinting at a shift toward resilient crops. Changes in flowering and fruiting times affect growing seasons, while pest increases and new weeds challenge farming. Rising cultivation costs, fewer traditional irrigation sources, and declining groundwater pose additional threats. These perceptions underline the complex challenges climate variability brings to farming and emphasize the urgent need for adaptive measures to support local agriculture.

Table: 1 Perception of respondents about impact of long-term climate change on agriculture in Ranchi

	Statement	A- Agree (%)	Un-decided (%)	D-Disagree (%)
1	Area under kharif crop has decreased	48.33	17.92-	33.75
2	Use of traditional crop varieties decreased	82.08	12.50	5.42
3	Changes occurred in flowering	48.3	32.50	19.17
4	Fruiting time of crops Cropping pattern has changed	82.92	15.83	1.25
5	Population of rodent like rat has increased	71.67	22.50	5.83
6	Emergence of new crop weed	67.09	29.16	3.75
7	Species Cost of cultivation increased	86.25	12.08	1.67
8	Traditional irrigation sources decrease	79.59	14.16	6.25
9	Well Ground water level has decreased	63.75	29.16	7.09

Based on Survey by- Kumari, N., Bara, N., Jha, B. & Kumar, R. (Effect of Climate Change on Agriculture and Allied Activities in Jharkhand: An Inference from Farmer Perception)

Mitigation Measures and Adaptation Prospects in Agriculture of Jharkhand

We have seen that agriculture of Jharkhand has struggling with impacts of climate change and will it have to cope with in future also. So, there is urgent need to mitigate to current bad impacts and adapt some resilient measures for future with sustainable ways.

The National Action Plan on Climate Change (NAPCC) was launched by the Government of India on June 30, 2008, under the guidance of the Prime Minister's Council on Climate Change (PMCCC). This ambitious and comprehensive policy framework aims to enable India to adapt to and mitigate the adverse effects of climate change while promoting sustainable development. It comprises eight national missions focused on key areas: the National Solar Mission promotes solar energy development; the National Mission for Enhanced Energy Efficiency targets energy savings; the National Mission on Sustainable Habitat emphasizes energy efficiency in urban planning; the National Water Mission aims to improve water use efficiency; the National Mission for Sustaining Himalayan Ecosystems focuses on conserving biodiversity and ecosystem health in the Himalayas; the Green India Mission targets afforestation and forest ecosystem restoration; the National Mission for Sustainable Agriculture supports climate-resilient agricultural practices; and the National Mission on Strategic Knowledge for Climate Change seeks to bolster research, knowledge, and climate science capacity. Together, these missions form a multi-pronged strategy addressing energy, agriculture, water, ecosystems, and knowledge generation to strengthen India's climate resilience and low-carbon growth pathway.

Various Missons were delegated to the different departments to prepare the sector specific policy, action/implementation planning, settings the goal and starting the implementation work. The Department of Science & Technology under the Ministry of Science & Technology was entrusted with the responsibility of coordinating two out of these eight national missions on climate change.

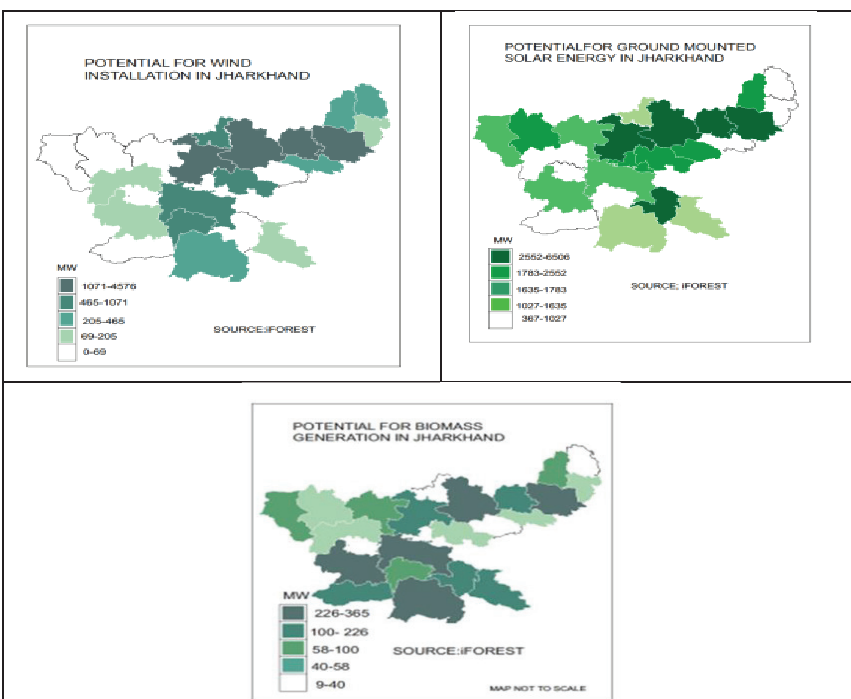
In light of above discussion, some pragmatic measures can be adapted to mitigate the risk and vulnerability of agriculture in Jharkhand:

1. Horticulture: Climate change, particularly in deficient precipitation, lessens the impact on horticulture crops, with the exception of vegetables. Mission for Integrated Development of Horticulture (MIDH) is a Centrally Sponsored Scheme for the holistic growth of the horticulture sector, covering fruits, vegetables, root & tuber crops, mushrooms, spices, flowers, aromatic plants, coconut, cashew, cocoa and bamboo. While the Government of India (GOI) contributes 85% of the total outlay for developmental programs in all the states except the states in the Northeast and Himalayas, 15% is contributed by state governments. In the case of Northeastern States and Himalayan States, GOI contribution is 100%. Similarly, for the development of bamboo and programs of the National Horticulture Board (NHB), Coconut Development Board (CDB), Central Institute for Horticulture (CIH), Nagaland, and the National Level Agencies (NLA), the GOI contribution will be 100%. The govt of Jharkhand has launched the Udyaan Development

Scheme. The scheme is aimed towards establishing and extending nurseries in the state. This will have nutritious fruits, plants, and vegetables. It will further develop the nutrition level of fruits and vegetables, a variety of flowers, banana cultivation, and house gardening. An allocation of Rs 5000 lakh has been proposed for the plan for 2017-18.

2. Alternative Energies- The present era is the machine era. Any sector of the economy needs energy for mechanized works. Crop harvest needs mechanized work. Machines or agricultural implements can utilize alternative energies to cut emissions of GHG. In Jharkhand, agricultural practices are still traditional. But slowly it moves towards mechanization and modernity. So, it needs use of alternative energy for sustainable agriculture in the wake of the climate change regime. forest, an organization has found alternative energy potentials, which have been presented through district-wise maps.

Map: 2 Spatial Distribution of Renewable Energy Generation Potential in Jharkhand: Wind, Solar & Biomass



3. Crop Diversification- Jharkhand is known for mono cropped rice cultivation under rainfed condition. Occurrence of frequent drought at intervals, low rainfall, long dry spell during crop season leads the farmers to shift towards low water requiring crops like Pulses, oilseed and cereals like Ragi and Jowar. Diversified cropping pattern and helps to cope with risk and uncertainty of crop failure.

4. Major Crop Resistance Variety – in tweak of climatic vagaries it is very necessary to develop resilient and resistant variety to sustain ups and downs climatic variability. Paddy crop is dominant in Jharkhand. It needs to develop robust variety to withstand against climate change in Jharkhand.

IRRI is gaining ground towards creating "C4" rice - rice with a supercharged photosynthesis component that is vastly improved at utilizing daylight to change over carbon dioxide and water into grain. C4 rice could yield up to half more grain than presently conceivable from existing rice assortments.

5. Irrigation Infrastructure- It is prime necessary to develop irrigation infrastructure to counter balance of climate change's vagaries for agriculture of the state. Pond irrigation will be more suitable than any other irrigation system because plateau rugged topography with hard rocks don't favourable for canal and tubewell irrigation. However, check dam system across rivulets will be more beneficial for agricultural fields.

6. Training of Farmers for Adaptation Climate Change- There is need to train and aware the farmers to adapt the farm practices according to changing climatic conditions in short term as well as long term. New developed climate resilient variety of crops should be provided to them.

7. Weather Forecast to Farmers- There should be a mechanism where farmers can get aware weather bulletins short-range and long-range forecast to accommodate their farm practices.

Conclusion

We have noticed that climate change occurs in Jharkhand and has affected the agricultural practices. It has worsened the risks of crop failure, lessened production, and disease-stricken crops. Regional climate change is caused by both local and global factors. This difference is very important because if a regional climate change occurs on account of local factors, then these changes can be mitigated by local actions. Jharkhand has prepared a climate change action plan for its agriculture sector. But it has to implement more conducive and pragmatic farm practices to mitigate the impacts of climate change on agriculture.

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HARNESSING POLICY INNOVATIONS IN GREEN FINANCE MANAGEMENT: UNLOCKING SUSTAINABLE DEVELOPMENT PATHWAYS IN INDIA

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Abstract

This paper emphasizes the role of green finance in advancing India's Sustainable Development Goals (SDGs) and examines various dimensions of green financing and its management meant for environmentally sustainable initiatives, including infrastructure development, public transport, renewable energy, recycling, and precision agriculture. Despite the significant potential of green finance, its adoption in India remains limited. Contributing factors include inadequate awareness among people and policy makers, lengthy project gestation periods, insufficient regulatory frameworks, and the lack of a comprehensive rating mechanism for green investments. The study *advocates for urgent policy reforms, such as the creation of a dedicated regulatory and rating agency, along with educational campaigns aimed at mitigating perceived risks and fostering wider acceptance of green finance as a vehicle for sustainable development.*

JEL: Q54, E44, G23

Keywords: Green Bonds Green Finance, Sustainable Investment

Introduction

Green financing is a relatively new concept aimed at supporting environment friendly initiatives through financial programs. This includes the production and supply of goods and services, as well as financial resources directed towards sustainability efforts (Al-Sheryani & Nobanee, 2020). Green finance encompasses projects related to renewable energy, energy efficiency, sustainable transportation, climate change mitigation, and advanced technologies to improve resource use and reduce environmental impact. Over time, green finance has evolved, driven by factors such as regulatory frameworks, capacity-building initiatives, institutions, technology, financial instruments, capital markets, and political environments (Bhatnagar & Sharma, 2022). Key instruments in green finance include green bonds, financial products, and regulatory frameworks that align with sustainability goals. A notable example is Australia's Clean Energy Finance Corporation, established in 2012, which has invested $10 billion in renewable energy projects (Gilmore et al., 2022). Successful green financing requires a robust framework, transparency, and stakeholder engagement, though challenges persist at both microeconomic and macroeconomic levels due to the diverse interests of stakeholders globally (Berensmann & Lindenberg, 2019).

Green finance plays a crucial role in advancing sustainable development for several reasons. Primarily, it helps combat climate change by focusing on renewable energy sources and improving energy efficiency. It also promotes the conservation of natural resources, reduces pollution, and protects biodiversity. Moreover, green finance creates opportunities by opening up of new markets, fostering investment in sustainable sectors, and generating employment (Vanishvili et al., 2022). Moreover, its long-term orientation contributes to stability of financial system, making it more resilient to environmental risks. The ultimate outcome of green finance covers, availability of clean water, air, and a healthier environment, benefiting all living beings. In essence, green finance offers a win-win scenario for individuals, governments, investors, and the planet, promoting both environmental sustainability and economic growth. Green finance, which fosters and supports sustainable investments, is a crucial catalyst for sustainable development in economies worldwide. According to the Sustainable Development Goals (SDGs), sustainable development entails meeting the economic and social needs of the present generation without compromising the ability of future generations to do the same, while addressing resource depletion, global warming, and climate change (Iqbal et al., 2021). Global warming is a serious concern and to limit global rise in temperature to 1.5°C, there is an urgent need for increased investment in environment friendly sectors (Azhgaliyeva & Liddle, 2020).

This paper examines the role of public and private financing in sustainable development, focusing on critical factors like climate change, resource depletion, social inequality, and economic growth. Mobilizing capital from both private and public entities is essential for supporting green investments, particularly in vulnerable sectors that require effective risk management to mitigate uncertainties related to climate change, market volatility, and technology disruption (Tran et al., 2020). Innovative financial instruments like green bonds and blended financing are crucial for funding projects with sustainable goals. Successful green financing requires specialized knowledge, technical assistance, and capacity building to reduce risks and ensure effective investment in sustainable practices.

State of Green Finance in India

Following its independence in 1947, India initially prioritized industrialization over green financing as it sought to catch up with countries that had undergone the Industrial Revolution. As a result, green financing is a relatively new idea within the Indian economic landscape. However, in recent years, it has gained significant momentum from policymakers. Notably, between 2017 and 2020, green finance in India grew by 150%, with contributions from both the public and private sectors. Public sector initiatives have led the way, with measures such as the issuance of green bonds, incentives for rooftop solar energy generation, subsidies for eco-friendly electric vehicles, and efforts to enhance energy efficiency (Bhatnagar & Sharma, 2021). Key domestic players in green finance include public sector banks like SBI, PNB, and BoB, along with private banks such as HDFC Bank, ICICI Bank, and Axis Bank. Non-banking financial companies (NBFCs), insurance companies, and government agencies like the Ministry of

Renewable Energy and SEBI also play significant roles. On the international front, organizations like the World Bank, the Asian Development Bank (ADB), the Asian Infrastructure Investment Bank (AIIB), and the New Development Bank (NDB) have provided substantial green financing for various projects in India.

Table 1: Green financing and investment statistics for India

Non-Fossil fuel capacity	207.76 GW (Increased by 396 % in the last 8.5 years)
Green bonds	$ 19.5 billion
Sustainable Investments	$ 19 billion
Estimated clean energy investments	$ 500 billion by 2030

Source: Invest India, Statista and Economic Times, 2021

Table 1 highlights that India's non-fossil fuel capacity, or renewable energy capacity, has grown by 396% over the past 8.5 years, reaching 207.76 GW as of 2021. Moreover, India has issued $19.5 billion in green bonds, with sustainable investments totaling $19 billion, and clean energy investments projected to reach $500 billion by 2030. However, several challenges hinder the growth of green financing in India, including a lack of awareness among the public, financial institutions, and policymakers (Singh, 2024). Furthermore, the long gestation periods of green projects conflict with the short-term return expectations of investors and institutions. The absence of a robust regulatory framework to oversee, control, and rate green financing and investments worsens the problem, leaving investors hesitant due to perceived risks (Bhatnagar & Sharma, 2021).

One of the primary challenges facing green finance is the lack of adequate data and transparency concerning green investments, which complicates risk assessments and hinders informed decision-making (Jankovic et al., 2022). Financial institutions often prefer projects with shorter gestation periods, while sustainable initiatives funded through green finance are typically long-term. This disparity leads to reluctance among financial institutions to extend capital, thereby obstructing sustainable development. Likewise, investors tend to be risk-averse, and turning their back on green finance projects due to perceived higher risks and extended timelines. In light of these issues, green finance must be distinguished from traditional monetary policy and viewed as a vital tool for addressing environmental challenges (Dziwok & Jäger, 2021).

In India, green finance and investments can be directed through financial products that encourage environmentally sustainable practices, support sustainable development, generate positive environmental impacts, and address climate change. For instance, green bonds help finance projects focused on renewable energy, energy efficiency, and sustainable agricultural practices, yielding substantial environmental benefits. Green loans provide funding for initiatives promoting environmental sustainability, while climate finance supports investments aimed at mitigating and adapting to climate change (Singh, 2024). Green finance plays a prominent role in India's pursuit of the Sustainable Development Goals (SDGs) and necessitates a comprehensive approach that merges innovative financial products with effective policy frameworks. To unlock its full potential, regulatory policies must be established to standardize green finance and investments, reduce perceived risks among investors, and ensure the availability of transparent data for analysis. In order to gain momentum of green finance in India, her green finance strategy should prioritize sectors such as renewable energy, sustainable agriculture, and climate change adaptation initiatives.

Unlocking Green Finance Initiatives: Case Studies and Best Practices

India has made significant strides in green finance, particularly in the renewable energy sector, which encompasses solar, wind, tidal, and hydropower. The National Solar Mission (NSM) plays a crucial role by providing financial assistance to solar plants across the country. Various state governments and the Union government also offer subsidies for installing rooftop solar panels on residential buildings and institutions. Furthermore, the Indian Renewable Energy Development Agency (IREDA) and the International Finance Corporation (IFC) facilitate loans for solar power plant installations. Wind and tidal energy projects also receive financing from several financial institutions, including banks and equity funds. The tidal power initiatives in India are predominantly funded directly by state and central governments, with limited public-private partnerships. Furthermore, green bonds and equity funds are offered by both government entities and private corporations and widening the investment landscape for sustainable energy.

Comparing India's green finance initiatives with those of China, the European Union (EU), and the United States (USA) reveals key differences that underscore both challenges and opportunities for India. China, a global leader in solar power generation, has developed a more advanced green bond market and a robust set of green finance policies, enabling large-scale investments that India could converge with. The EU offers valuable insights through initiatives like the Sustainable Finance Disclosure Regulation (SFDR), which promotes transparency and accountability in green financing, and its ambitious climate goals provide a roadmap for India to follow. Meanwhile, the USA's vibrant green investment market, backed by an active lending system and well-established sustainable finance frameworks, demonstrates the potential for growth and innovation in India's green finance ecosystem. By adopting best practices from these global leaders, India can strengthen her green finance strategy, better align with their sustainable development goals, and contribute more effectively to global climate action.

India has substantial opportunities in green financing that can drive sustainable development and attract investments. One promising approach is the creation of a Green Investment Fund, supported by a strong regulatory framework that includes the issuance of green bonds with attractive tax incentives. Prioritizing investor education on the benefits and opportunities of green investments, while incorporating global best practices, can enhance the fund's credibility and appeal to international investors (Gupta & Kumar, 2022). Additionally, promoting green banking and finance aligned with financial inclusion goals can ensure that low-income and marginalized communities benefit from sustainable financial products. To incentivize green lending and investment, appropriate institutional incentives must be devised. Furthermore, advanced technologies such as Artificial Intelligence (AI) can be employed for risk assessment, allowing financial products to be tailored to the specific needs of these communities (Dwivedi et al., 2023).

Financing sustainable infrastructure development in areas such as renewable energy, energy grids, and green transportation systems through public-private partnerships act as a key opportunity for green finance in India. Green bonds can play a crucial role in funding these projects, provided with environmental impact assessments and sustainability evaluations conducted to ensure long-term viability. For these investments to succeed, coordinated policies across institutional levels are essential, along with data availability to enable informed decision-making. International cooperation is also critical for sharing knowledge, best practices, and technical expertise (Singh & Sharma, 2023). By leveraging these avenues, India can make significant progress toward its sustainability goals while driving economic growth.

However, a key challenge lies with the lack of standardization in defining and categorizing green investments, which complicates the differentiation between green and non-green finance. The ambiguity in classifying short-term and long-term projects further deters investors, as they are concerned about risks and returns associated with green projects with majority of which have long gestation periods and slower returns (Marcus et al., 2011). Additionally, the absence of transparent data raises concerns over greenwashing, where firms manipulate information to appear more environmentally friendly than they are (Chen & Feng, 2019). Limited investor awareness of green finance options, along with high upfront costs, contributes to a preference for traditional energy sources that require lower preliminary capital. Furthermore, weak management of green investment opportunities and insufficient guidelines for addressing environmental and social risks exacerbate investor hesitation, underscoring the need for stronger regulatory frameworks and clearer standards (Chen & Feng, 2019).

The following two case studies illustrate specific green finance projects in India, shedding light on the challenges commonly faced within the sector. These examples offer a clearer understanding of the issues surrounding green financing and highlight the obstacles that need to be addressed.

Case study 1

Solar power project in rural Rajasthan

A solar power project was launched in 2017 in the 24 APD village near Anoopgarh, in the Sriganganagar district of Rajasthan, with the support of village cooperatives. The initiative aimed to provide rooftop solar electricity to its members by installing solar panels on their house rooftops and barren land, enabling them to sell excess electricity to the grid through an interconnected system. The project was designed to recoup its capital investment within a few years and generate profits thereafter. It was anticipated that the project would produce 33,000 units of electricity, with a daily average of 100-120 units, allowing 10,000 units to be sold to the power grid after meeting domestic consumption of 23,000 units. However, the project encountered significant challenges in attracting participants due to the high initial upfront costs of the solar panels and installation charges. When the village cooperatives sought ‘green finance’ from financial institutions, they found that these institutions preferred shorter repayment terms, which contrasted with the longer gestation period required for the solar project. Participants were unable to accept these terms, as they could begin repayment only after the project started generating profits. Furthermore, the substantial upfront costs discouraged members of the cooperative society from registering for the project, as they were skeptical about securing the necessary funds. Consequently, the project failed to achieve its expected outcomes and can only be considered a moderate success, despite its noble ambitions and intentions, primarily due to the lack of accessible “green finance.”

Case study 2

Green building project in Mumbai

A green building project was proposed by a developer in Mumbai, incorporating numerous sustainability features such as rainwater harvesting and energy-efficient, eco-friendly construction materials that align with global environmental standards. Despite the developer’s eco-friendly construction plan addressing the contentious space shortage in a metropolitan city like Mumbai, the initiative struggled to attract investors. One of the primary challenge was that investors found it difficult to grasp the unconventional concept of a green project and were cynical about the associated risks and expected returns. The developer also faced challenges in effectively communicating the importance and benefits of green construction, including its longevity, cost-effectiveness, and potential returns. This disconnect stemmed from a general lack of awareness among investors and insufficient educational initiatives from relevant authorities. Had there been a clear green building rating system and awareness campaigns to better categorize developers, the situation could have been markedly different, potentially attracting a significant number of interested investors. Moreover, investors expressed doubt regarding the long-term environmental benefits of such projects and raised concerns about the lack of a robust framework for managing and accessing the potential social impacts on construction workers involved in the project. As a result, the initiative ultimately failed to secure “green finance” from prospective investors.

Opportunities for Growth and Innovation through Green Finance

This section explores several promising areas for expanding green finance in India, capitalizing on the country’s tropical climate, which is characterized by abundant sunlight and significant rainfall, particularly in the Western Ghats and the Himalayan region. These natural resources present valuable opportunities for harnessing renewable energy through solar, wind, and hydropower. Green financing can enable the installation of solar panels on rooftops of commercial buildings, railway stations, and residential buildings, fostering solar energy generation. Besides, India's extensive coastline and hilly terrain make it suitable for wind energy production, while hydropower can be harnessed from the streams flowing down the Ghats and the Himalayan Mountain ranges. Moreover, green finance can support sustainable agricultural practices, such as organic farming that reduces reliance on chemical fertilizers and pesticides (Gupta et al., 2021). Investments in precision agriculture, utilizing remote sensing technology and the Internet of Things (IoT), can optimize water usage and minimize the environmental impact of agricultural inputs, ultimately enhancing crop yields (Adhikari et al., 2022).

Another promising avenue for green finance is the development of green infrastructure, which encompasses investments in green buildings, public transportation systems, and urban green spaces that enhance air quality. Such initiatives can lead to significant reductions in energy consumption while improving the quality of life for urban residents. Besides, green finance can support water conservation efforts through investments in wastewater treatment facilities, pollution reduction infrastructure, wetland conservation, waste management, recycling, and energy conservation. Furthermore, green investments promoting green transportation, such as electric vehicles and charging stations alongside roads to strengthen public transport that can decrease reliance on private vehicles running on fossil fuels, thereby contributing to sustainable development in India.

To ensure the effective functioning of green financing and investments, the development of innovative financial instruments is essential. Green bonds are a prominent tool in this space, operating similarly to traditional bonds but offering returns specifically linked to projects that prioritize sustainability outcomes. In addition to green bonds, blue bonds focus on marine conservation and the sustainable management of ocean resources. Sustainability-linked loans present another opportunity that tying loan terms to predefined sustainability targets, which align the interests of lenders and borrowers. Transitional loans, designed to fund investments aimed at reducing greenhouse gas emissions and promoting sustainable practices, further enhance green financing efforts.

Emerging areas such as climate tech funds are becoming crucial for combating climate change, while green infrastructure funds support the development of infrastructure that underpins a green economy. Sustainable insurance also offers affordable coverage for green properties and addresses climate-related risks. However, identifying genuine green finance and investments remains a significant challenge. Advanced technologies, including block chain, Artificial Intelligence (AI), and Machine Learning (ML), can improve the identification of tokenized green products generated through sustainable practices. These technologies facilitate traceability, transparency, and risk coverage, making sustainable investments more accessible to a broader range of investors (Vegesna, 2023).

Key Drivers and Policy Suggestions of Green Finance

To promote, materialize, and regulate the concept of green financing in India, the Reserve Bank of India (RBI) plays a critical role alongside the SEBI. The RBI has initiated the Network for Greening the Financial System (NGFS) to enhance disclosures related to climate risks associated with various infrastructure and industrial projects. This initiative aids in monitoring and managing these risks, supports the issuance of green bonds, and provides incentives for financial institutions to engage in green lending. A notable example of a target promoting green financing is the *'Panchamrit'* initiative, which aims to generate 50% of India's energy from non-conventional sources (KM et al., 2022). However, significant challenges persist in the green finance sector, including a substantial finance gap relative to the ambitious targets set and a lack of clarity in standardizing the measurement of the social impact of projects financed through green initiatives. Addressing these challenges is essential for the successful implementation and growth of green financing in India.

As awareness of climate change issues continues to grow, the demand for sustainable investment opportunities has surged, particularly among Millennials and Gen Z. This demographic is increasingly drawn to green investment options like equity shares and mutual funds, driven by the promise of attractive returns and substantial institutional support in a rapidly expanding market (Schmid et al., 2021). However, this rising interest has also heightened concerns about transparency, particularly with the phenomenon of 'green washing,' where companies inflate their environmental credentials to attract environmentally conscious investors. To preserve the integrity of green finance and safeguard investors, it is essential to implement robust standards and transparency measures that effectively address these risks. Establishing clear guidelines and accountability frameworks will help ensure that green investments deliver on their promises and genuinely contribute to sustainability goals.

Technological advancements are critical in driving investments in green projects, transforming the energy landscape through innovations in solar energy generation, wind power, and enhanced battery storage capabilities. Optimized grid management systems improve overall efficiency, while energy-efficient buildings with automated lighting, heating, and cooling aim to reduce consumption using sustainable materials. Emerging opportunities in precision agriculture, recycling, and environmental monitoring are also gaining traction, with Artificial Intelligence (AI) identifying viable investment areas and block chain technology enhancing transparency in green firms. To support this growth, robust policy measures are essential, including incentives for green investments, clear standards for green finance, and capacity-building initiatives. Tax benefits for projects utilizing energy-efficient technologies and the promotion of green bonds can further stimulate sustainable investments. Moreover, subsidies for electric vehicles and renewable energy infrastructure are crucial. Establishing a standardized green taxonomy and a certification system will enhance the credibility and marketability of green finance instruments, fostering a more accessible investment landscape (Dong et al., 2024; Debbarma & Choi, 2022).

Awareness of green finance among stakeholders in India is currently limited, highlighting the need for capacity-building initiatives focused on education and training for investors, businesses, and policymakers. Providing technical assistance to emerging industries and conducting regular awareness campaigns are essential for fostering a deeper understanding of green finance. As these concepts are relatively new within the context of Sustainable Development Goals (SDGs), a robust regulatory framework is urgently required. Access to transparent data is crucial for researchers to analyze environmental and financial risks associated with green investments, while establishing systems for international cooperation can facilitate knowledge sharing and the exchange of best practices. The growing demand for sustainable products, driven by technological advancements that reduce production costs and enhance the viability of green investments, further emphasizes this need. To effectively integrate green finance into broader economic and sustainable development strategies, India must establish a comprehensive framework that sets clear objectives for reducing greenhouse gas emissions, promoting sustainable consumption, and enhancing energy efficiency. By defining specific and measurable targets, the country can align financial initiatives with environmental goals, driving significant progress toward a more sustainable economy.

To achieve policy coherence, it is vital to establish mechanisms that coordinate policies across various departments engaged in climate change, renewable energy, and sustainable development. This harmonization will enable coordinated efforts, ensuring that, initiatives in one sector do not conflict with or undermine objectives in another. Central to this effort is the establishment of a dedicated agency responsible for overseeing green finance activities. This agency would monitor progress, evaluate the impact of green finance initiatives, and facilitate collaboration among stakeholders, including government bodies, financial institutions, and the private sector. By centralizing these efforts and providing clear direction, the agency can significantly advance India's green finance agenda, fostering a sustainable economic environment that benefits both the economy and the environment.

Conclusion

Green financing is crucial in promoting sustainable investments in infrastructure, renewable energy, and agriculture, all of which are essential for achieving the Sustainable Development Goals (SDGs). Financial instruments like green bonds, blue bonds, green insurance, and financing for precision farming are designed to reduce and optimize energy consumption. The capital raised through these instruments is exclusively allocated to environment friendly economic activities, thereby contributing to a greener economy. However, significant challenges impede the widespread adoption of these ideas. A major constraint is the lack of awareness among individuals and institutions regarding green financing and its associated investment opportunities. Furthermore, the difficulty in distinguishing between green and non-green finance complicates the investment landscape. The absence of a robust regulatory framework and inadequate rating agencies exacerbate these challenges, making it difficult for investors to assess the risks and returns associated with green investments. To address these obstacles, policymakers must prioritize initiatives that promote green financing through comprehensive education and awareness campaigns targeted at stakeholders. Establishing a dedicated rating agency and regulatory body could help mitigate the perceived risks and uncertainties linked to green financing. By implementing these measures, barriers to green investment can be significantly reduced, fostering a more conducive environment for green initiatives, and ultimately supporting the global commitment to sustainable development.

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8.

DIGITAL DIVIDE TO DIGITAL OPPORTUNITY: TECHNOLOGY-ENABLED LEARNING AND EDUCATIONAL EQUITY IN INDIA

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ABSTRACT

The digitalisation of education in India is an essential journey along the path towards meeting Sustainable Development Goal 4 (SDG 4) - that of inclusive and equitable quality education for all. This chapter traces India's development from digital divide to digital opportunity in education, looking at the impact that technology-enabled learning initiatives have had on addressing educational inequalities as well as bringing about new challenges. The research delves into the effect of flagship initiatives such as Digital India, PM eVIDYA, and SWAYAM on access to education, especially in rural and disadvantaged areas. Through an in-depth analysis of policy schemes, program implementation, and on-ground results, this chapter shows that although digital initiatives have helped spread education, gaps in infrastructure, digital literacy, and content localization continue to persist. The COVID-19 pandemic helped speed up digitalization but also brought existing gaps into focus. Case studies across different Indian states provide evidence of successful technology integration models, whereas empirical evidence indicates quantifiable learning outcomes and teacher capacity

improvement. The chapter concludes that India's digital learning revolution needs long-term investment in infrastructure, teacher capacity building, and inclusive design to maximally achieve SDG 4 targets. Future paths involve artificial intelligence integration, vernacular content creation, and public-private partnerships towards a sustainable educational technology ecosystem.

Keywords: digital divide, digital education, educational equity, India, SDG 4, technology-enabled learning

INTRODUCTION

The quest for Sustainable Development Goal 4 (SDG 4) - inclusive and equitable quality education and lifelong learning opportunities for all - comes with special challenges and opportunities in the Indian context. India has more than 250 million students in formal schooling and heterogeneous linguistic, cultural, and socio-economic contexts, and its education system is one of the globe's most intricate educational environments. The use of digital technologies in education has become a powerful driving force, which has unprecedented possibilities to close the educational gaps while at the same time generating new types of digital divides. India's digital learning journey accelerated with the announcement of the Digital India initiative in 2015, which conceptualized turning the nation into a digitally empowered society and knowledge economy (1). The education sector was the target of digital transformation as initiatives were pursued to use technology to improve access, equity, and quality in education. Yet, the journey from digital divide to digital opportunity has been characterized by both spectacular success and abiding challenges, most prominently during the COVID-19 pandemic when millions of children experienced education disruption through absence of digital access.

POLICY FRAMEWORK AND DIGITAL EDUCATION INITIATIVES

National Education Policy 2020 and Digital Vision

The National Education Policy (NEP) 2020 was a turning point in India's educational revolution, categorically identifying technology as an important facilitator of education goals attainment (2). The policy is driven by the imperative of a robust digital infrastructure, which involves high-speed internet connectivity, digital hardware and software, and good digital content.

The NEP 2020 follows SDG 4 by championing inclusive learning while harnessing technology to extend reach to marginalized groups.

The policy framework defines a number of important principles for digital education: universal access to digital infrastructure, indigenous development of digital platforms, development of multilingual content, and converging emerging technologies such as artificial intelligence and virtual reality. These principles align directly with the multidimensional character of educational inequity in India and offer a strategy for systemic change in order to transform the education sector.

Digital India Initiative in Education

The 2015 Digital India program set the stage for India's digital revolution in education (3). The program has three major pillars: development of digital infrastructure, promotion of digital literacy, and digital delivery of services. In the context of education, this meant the launch of some flagship programs aimed at improving access and quality through technology adoption.

The initiative's influence on education has been immense, with huge investments in school connectivity and digital infrastructure. The initiative has enabled the creation of several e-learning platforms and digital assets, revolutionizing how education is accessed and delivered nationwide. The success of the initiative is that it has a holistic approach and tackles not only technology rollout but also capacity development and content creation.

PM eVIDYA: Comprehensive Digital Education Platform

The PM eVIDYA program, introduced in 2020, is India's most ambitious digital learning program to offer multi-mode access to education in the time of the COVID-19 pandemic (4). The program includes television channels (SWAYAM Prabha), radio programs (Shiksha Vani), and online portals (DIKSHA) to establish a holistic ecosystem for digital learning that considers varied connectivity and device access cases.

SWAYAM Prabha, a cluster of 34 direct-to-home television channels, telecasts educational programs for children from classes 1-12 in various countries and languages. The programme has been especially helpful for students in rural areas with poor internet connectivity. The multilingual strategy, wherein the content is delivered both in Hindi, English, and regional languages, has greatly improved convenience for various student groups across India's multilingual structure.

SWAYAM: Massive Open Online Courses Platform

The Study Webs of Active-Learning for Young Aspiring Minds (SWAYAM) website, initiated in 2017, is India's own initiative to massify higher education in the form of Massive Open Online Courses (MOOCs) (5). The website hosts courses in diverse subjects ranging from engineering to humanities and provides quality education to millions of learners transcending geographical and economic boundaries.

The integration of the platform with formal education systems by credit transfer mechanisms has opened up avenues for access to good content by high-quality institutions by students. The success of SWAYAM indicates the potential of open educational resources in reducing educational inequity, especially in higher education where access to quality institutions is still a distant dream for many students.

DIGITAL INFRASTRUCTURE AND CONNECTIVITY CHALLENGES

Rural-Urban Digital Divide

The rural-urban digital divide continues to be one of India's biggest issues in achieving educational equity. Urban regions have made more progress toward digital connectivity, but rural regions still fall behind in internet access, equipment availability, and digital literacy. This gap has a direct effect on access to education, as was shown during the COVID-19 pandemic when rural students had a harder time obtaining online education (6).

The government has undertaken various programs to tackle this chasm, such as the National Optical Fibre Network (NOFN), subsequently renamed BharatNet, to connect gram panchayats with high-speed internet connectivity. The progress was slowed down due to implementation issues, maintenance problems, and last-mile connectivity problems in providing universal digital access for education.

Device Accessibility and Affordability

Availability of digital devices continues to be an overarching barrier to digital education adoption in India. The difference in device ownership between rural and urban India, as well as between socio-economic communities, poses enormous challenges to the rollout of digital education programs. Penetration of smartphones, though growing very fast, continues to reflect enormous disparities that impact access to education (7).

Government efforts have tried to make devices accessible by various programs, such as device distribution plans and subsidized access initiatives. Nevertheless, the extent of the need greatly surpasses the current provision, necessitating continued investment and innovative financing models to provide universal access to digital learning devices.

Internet Connectivity and Quality

Quality of internet connectivity has a critical bearing on the efficiency of digital education programs throughout India. Although coverage of mobile internet has grown fast, data speeds, dependability, and affordability are still not uniform, especially in rural and distant locations. This is exacerbated by high data prices compared to income for most families (8).

Government actions have included zero-rating educational content and student subsidies for data access, but more extensive solutions need to involve persistent investment in telecommunications infrastructure and regulatory architectures enabling education access.

DIGITAL LEARNING PLATFORMS AND CONTENT DEVELOPMENT

DIKSHA: National Digital Infrastructure for Teachers

The Digital Infrastructure for Knowledge Sharing (DIKSHA) platform, which was introduced in 2017, is the national platform for learning and teaching resources in India (9). The platform offers varied educational content across languages and subjects, facilitating teachers and students throughout their learning process through readily available digital resources.

The power of DIKSHA is its multilingual vision, with content being offered in many Indian languages. The linguistic pluralism has proved essential in addressing various student communities spread across India's multilingual scenario. Integration of the platform with QR code technology in textbooks has provided effortless entry into digital content, and students have been able to access add-ons with ease.

Content Localization and Vernacular Education

The creation of vernacular educational content has been a focal area of India's digital education agenda. Studies prove that students studying in the mother tongue exhibit much higher understanding than students studying through non-native languages (10). This has propelled efforts to produce quality educational content in local languages in India's multilingual environment.

The popularity of vernacular content can be seen through numerous digital platforms that provide content in more than one Indian language and have made deep inroads in the non-English speaking territories. The government has also been concentrating on the development of vernacular content, with national educational organizations creating digital content in various Indian languages.

Quality Assurance and Content Standards

Quality in digital learning content is still a major issue in India's increasingly growing digital learning environment. Lack of standardized quality frameworks has resulted in mixed content quality among platforms and providers. The government has countered by putting in place guidelines and frameworks for educational technology and content quality (11).

Efforts have been made to create indigenously based technologies for learning devices and platforms, coupled with quality and security in education infrastructure, to promote digital education. These initiatives are aimed at India being self-reliant in educational technology with standards for the quality of learners.

IMPACT ASSESSMENT AND LEARNING OUTCOMES

Quantitative Impact Analysis

Empirical evidence on the effects of digital learning programs in India shows varied but overall positive results. Evidence suggests that students with access to digital resources for learning experience improvements in outcomes relative to non-players, though the effects are highly dependent on the quality of implementation and facilitating infrastructure (12).

Several evaluation reports offer evidence of digital education impact in rural India, reflecting improved access to educational use of smartphones among children in rural areas. Yet the data also points to difficulties in sole access to educational resources, calling for enhanced digital literacy and content development.

Teacher Capacity Building and Digital Literacy

The success of digital education programs greatly relies on teacher capacity and digital literacy. Millions of teachers have been reached through national teacher training programs in digital pedagogy and technology integration (13). Nevertheless, research suggests that ongoing support and continuous professional development are needed to integrate technology effectively in the classrooms.

Evidence proves that educators receiving complete digital training are more effective in leveraging educational technology than those who receive minimal training. Implications highlight the importance of integrated teacher development methods that bring together technical competencies and pedagogical content knowledge for effective implementation of digital education.

Student Engagement and Learning Preferences

Online learning has had a tremendous effect on student engagement trends throughout India. Research indicates that interactive online content enhances student interest and participation levels over and above conventional teaching approaches (14). However, effectiveness is determined by age groups where students who are younger adapt more to digital learning environments.

Student interest in online learning has grown immensely, especially among secondary school students. Studies show that students more and more favor blended learning methods that integrate digital and face-to-face ways, with significant consequences for future educational design and delivery models.

CASE STUDIES: STATE-LEVEL INNOVATIONS

Kerala: IT@School Initiative

The IT@School program introduced in 2001 by Kerala is one of India's best state-level digital education initiatives (15). The initiative has realized state-wide access to digital education in state government schools, with wide digital infrastructure and connectivity in schools across the state.

The success of the initiative is due to its holistic approach, integrating development of infrastructure, teacher training, and content development. The program has created voluminous digital content in Malayalam, which shows the significance of local content in digital learning. The initiative has shown quantifiable improvements in the performance of students, especially in mathematics and science streams.

Rajasthan: Digital Education Transformation

Rajasthan's digital education revolution prioritizes to meet the special needs of desert geography and dispersed populations. Innovative solutions have been adopted by the state, such as satellite connectivity and mobile learning units that penetrate far-flung villages and settlements (16).

The state's online education initiatives have met with success in enhancing access to education, through enhanced school enrollment in the intervention districts. The efforts have registered impressive growth among girl students and scheduled castes and tribes students, exemplifying how customized digital solutions can target specific geographical and demographic issues.

Karnataka: Public-Private Partnership Model

The strategy of Karnataka towards digital education is based on public-private partnerships and educational technology innovation. The state has partnered with IT companies to innovate learning solutions in a manner that retains public sector control and quality while creating customized solutions (17).

The Karnataka experience illustrates the catalytic impact of government-private sector partnerships in upscaling digital education solutions. The emphasis of the state on outcome measurement and ongoing improvement has spawned models that can be replicated in other states in India.

CHALLENGES AND BARRIERS TO DIGITAL EDUCATION

Socio-Economic Barriers

Socio-economic conditions strongly influence access and efficiency of digital education all over India. Low-income families generally cannot afford devices, connectivity, or the opportunity cost of kids spending time on digital learning rather than income-generating activities. This is disproportionately affecting lower-income family and marginalized students (18).

Gender inequalities also continue to exist in access to digital education, with girls enjoying less access to digital technology than boys, mirroring wider gender disparities within Indian society. Tackling these inequalities needs special interventions that take social and cultural influences as well as technological responses into account. Infrastructure and Technical Challenges

With considerable investments, infrastructure issues still constrain digital education efficacy in India. Irregularities in power supply prevail in most rural schools, hindering extended digital learning. Internet connectivity is weak and unstable in most places, with constant outages disrupting learning continuity (19).

Technical support and management of digital infrastructure pose recurring challenges to education institutions. Most schools do not have technical staff to troubleshoot and maintain digital systems, resulting in underutilization of equipment and decreased efficiency of digital educational initiatives.

Digital Literacy and Pedagogical Integration

Levels of digital literacy among students and teachers are still unequal in the country. While cities have experienced accelerated growth in digital proficiency, rural regions still fall far behind. The gap impairs the successful deployment of digital education programs (20).

The embedding of digital technologies into pedagogical approaches is still daunting for most teachers. Most employ digital tools for the delivery of content but find it difficult to incorporate them meaningfully into engaging learning activities, necessitating long-term professional development and institutional support.

COVID-19 IMPACT AND EDUCATIONAL TRANSFORMATION

Accelerated Digital Adoption

The COVID-19 pandemic spurred unparalleled digital adoption within India's education system. The swift shift to online schooling was one of the largest digital experiments in world history, with hundreds of millions of students relocating to digital learning platforms (21). The swift shift exposed both the promise and limitations of the country's digital education infrastructure.

The pandemic era witnessed tremendous growth in digital learning platforms and utilization. Public platforms witnessed tremendous spikes in utilization, while private ed-tech companies witnessed tremendous upticks in registrations. Yet, this growth also brought to the fore existing disparities, as millions of students could not avail themselves of online learning because of infrastructural constraints.

Learning Loss and Recovery Strategies

The effect on learning outcomes of the pandemic has been huge all over India. Several studies have reported considerable learning loss when schools were closed, with more effect on students from poor backgrounds (22). Both mathematics and language abilities had the highest decline, with rural children having higher learning loss than urban children.

Recovery efforts have emphasized hybrid learning strategies that blend digital and conventional methods. The programs of the government have been augmented and adjusted to mitigate learning gaps, and National Education Policy 2020 implementation has been hastened to facilitate educational transformation and recovery.

Innovation and Adaptation

The pandemic era saw tremendous innovation in the delivery of education throughout India. There was innovative problem-solving by teachers leveraging existing technology, such as social media sites and community-based learning strategies. TV channels were redirected for education programs, reaching millions of students who lacked internet connectivity (23).

The community-based models of learning arose as successful substitutes for official digital education, as village-level digital learning hubs offered communal access to digital facilities and assistance. The models prove the significance of community involvement in digital learning success and continuation.

Industry Partnership Models

India's digital learning ecosystem has gained tremendously from public-private partnerships across different initiatives. Large technology firms have partnered with government initiatives to offer infrastructure, content, and technical support, leading to durable models for scaling digital learning solutions (24).

These alliances have combined innovation and efficiency of the private sector with equity and accessibility orientation of the public sector. Balancing education objectives with commercial interests is still a challenge necessitating sensitive governance and oversight processes. EdTech Sector Growth

India's EdTech industry has grown exceedingly well, facilitated by rising internet penetration, smartphone uptake, and the shifting sentiments towards online learning (25). The sector has witnessed massive investment and an active ecosystem of edtech firms.

The industry success has fueled innovation in digital delivery of education and content creation. Sustainability issues and market trends, however, need to be constantly watched to make sure that there is continued innovation and availability to all strata of the population.

Quality Assurance and Regulation

The EdTech industry's growth at breakneck speeds has raised critical questions regarding the quality assurance and consumer protection of digital education. The creation of regulatory frameworks and quality standards has grown as crucial for effective and safe digital learning environments (26).

Industry associations' initiatives for self-regulation have come to serve as parallel measures to government regulation, with voluntary industry standards for content quality, data privacy, and consumer protection proving to be a testament to industry dedication to responsible growth and development.

FUTURE DIRECTIONS AND EMERGING TECHNOLOGIES

Artificial Intelligence and Personalized Learning

Artificial intelligence technologies are starting to revolutionize digital learning in India, providing opportunities for learning experiences tailored to individual needs and learning habits of students. AI-driven platforms can deliver tailor-made educational material and testing, with the potential to enhance learning outcomes substantially (27).

A number of Indian institutions and firms are creating AI-driven education solutions, ranging from adaptive learning systems to intelligent tutoring systems. These solutions have special potential for addressing the heterogeneous learning demands of India's student base.

Virtual and Augmented Reality Applications

Virtual Reality and Augmented Reality technologies are offering new avenues for immersive learning experiences that have the potential to increase educational engagement and comprehension. Initial implementations in Indian learning environments have been encouraging in terms of complex concept visualization and recall (28).

Schools are starting to look into VR and AR uses in subjects such as science, history, and geography, where visualization and immersion can significantly improve learning and student engagement.

Blockchain and Credential Verification

Blockchain technology is on the horizon as a promising solution for credential verification and academic record keeping in India's education sector. This technology would be able to handle issues of certificate forgery and enhance credential portability across institutions (29).

The use of blockchain-based systems to authenticate academic credentials has the ability to transform the process of recording, authenticating, and transferring educational accomplishments, enhancing lifelong learning and skill development efforts.

POLICY RECOMM

In order to take full advantage of digital education, India needs to make high-speed internet connectivity, assured power supply, and adequate digital devices a priority for all schools in the overall development of infrastructure. A national digital education infrastructure fund can finance steady investment in these sectors of utmost importance.

The development of infrastructure must be through integrated planning methodologies, and regional digital education centers will act as resource centers for schools in the surrounding areas. This will help to maximize resources while providing technical support and maintenance capacity across the system.

Teacher Development and Capacity Building

Systematic teacher development programs are paramount for successful implementation of digital education throughout India. The programs must incorporate training in technical competencies in addition to pedagogical skills, while emphasizing effective integration of digital tools into instructional practices through continuous professional development (30).

A country-wide digital education teacher certification program would offer uniform training and certification for teachers nationwide, guaranteeing uniform quality and impact of digital education delivery.

Equity and Inclusion Strategies

Digital education equity needs special targeted interventions for disadvantaged groups, such as concessional access to devices and connectivity, indigenous language content development at tribal and regional levels, and learning material in an appropriate cultural setting. Girl students and students with disabilities must receive special attention (31).

Community-based learning centers have the potential to act as efficient intermediaries, with collective access to digital content and assistance from trained facilitators who can help students and families to navigate digital education systems and tools.

CONCLUSION

India's transition from digital divide to digital opportunity in education is a transformative experience that showcases both the promise and the pitfalls of using technology to meet SDG 4 targets. The end-to-end policy framework through such initiatives as the National Education Policy 2020, Digital India, PM eVIDYA, and SWAYAM has laid a robust foundation for technology-facilitated learning that reaches millions of students from different geographic and socio-economic backgrounds. Still, ongoing challenges in infrastructure, digital literacy, and access require continued focus and systemic interventions. The COVID-19 pandemic accelerated digital adoption while highlighting existing inequalities, emphasizing the need for inclusive approaches that address the digital divide through comprehensive infrastructure development, teacher capacity building, and community-based solutions. The success of state-level innovations in Kerala, Rajasthan, and Karnataka demonstrates the potential for tailored approaches that address specific regional challenges while leveraging public-private partnerships for sustainable scaling. In the future, India's digital education revolution needs to center on emerging technologies such as AI and VR, improve quality control systems, and make the advantages of digital education accessible to all groups in society, especially marginalized ones, in order to fulfill the vision of inclusive and equitable quality education for all.

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10.

TWIN EPIDEMICS: ADDRESSING THE INTERPLAY BETWEEN MENTAL HEALTH AND NON-COMMUNICABLE DISEASES IN ACHIEVING SUSTAINABLE WELL-BEING IN INDIA

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Abstract

India faces intersecting public health crises: escalating prevalence of non-communicable diseases (such as diabetes, hypertension, and cardiovascular conditions) alongside significant mental health burdens. The bidirectional relationship—where NCDs increase risk of mental illness and vice versa—creates a "twin epidemic" that undermines Sustainable Development Goal 3 targets for ensuring healthy lives and promoting well-being. This chapter examines prevalence, comorbidity patterns, risk factors, SDG alignment, policy responses, and integration opportunities. Drawing on national surveys, peer-reviewed studies, and recent screening data, we illustrate how India's response needs to move from siloed approaches to integrated care models. Recommendations include systemic changes in primary health centers, task-shifting, digital platforms, and strengthened policies, with emphasis on equitable access and stigma reduction. Graphical data highlight NCD mortality shares (Figure 1) and mental health DALYs from recent datasets to underscore urgency.

Keywords: *Mental health, Non-communicable diseases, Comorbidity, India, SDG 3, Integrated care, NCD–mental health interplay, Health systems.*

Introduction

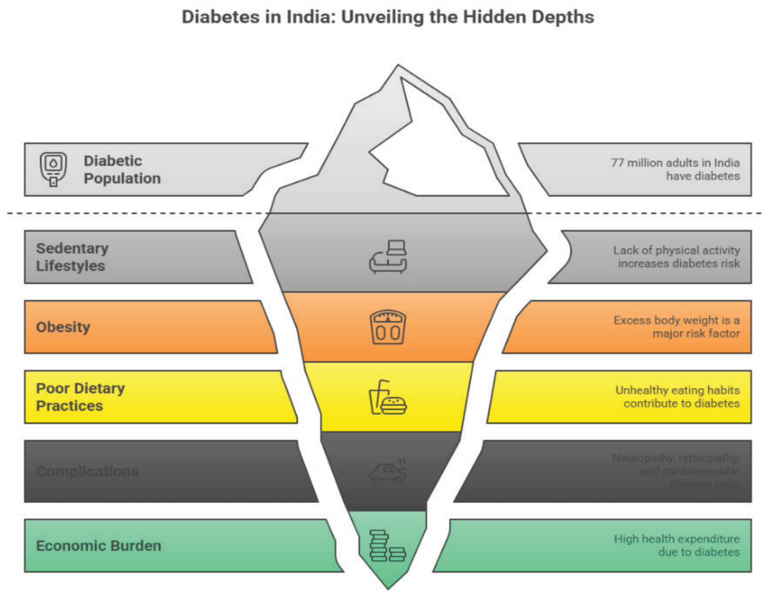
Under the framework of Sustainable Development Goal 3 (Good Health and Well-being), India has committed to reducing premature mortality from non-communicable diseases (NCDs), improving mental health outcomes, and addressing treatment gaps to ensure holistic well-being for its population. Despite these commitments, the country continues to face significant challenges due to what can be termed as a "twin epidemic" of NCDs and mental health disorders. Non-communicable diseases currently account for nearly 60% of all deaths in India, making them the leading cause of mortality and morbidity.

Among these, cardiovascular diseases alone are responsible for approximately 24% of total deaths, chronic respiratory diseases for 11%, cancers for 6%, and diabetes for around 2% (World Health Organization [WHO], 2021). These conditions not only reduce life expectancy but also impose a long-term economic and social burden, particularly in low- and middle-income households. Simultaneously, India has witnessed a growing prevalence of mental health disorders, with an estimated 197 million individuals affected by 2017, contributing to 4.7% of total Disability-Adjusted Life Years (DALYs)—a significant increase from 2.5% in 1990 The 2016 National Mental Health Survey further highlighted the magnitude of the crisis, reporting a lifetime prevalence of any mental morbidity at 13.7% and revealing an alarming treatment gap of more than 84%, particularly in rural and underserved regions

These two public health burdens—NCDs and mental health conditions—do not exist in isolation but often reinforce one another, with evidence suggesting that chronic illnesses heighten the risk of depression and anxiety, while untreated mental disorders increase the vulnerability to lifestyle-related diseases. This intricate interplay underscores the urgent need for integrated approaches to healthcare that simultaneously target both physical and mental health, if India is to achieve sustainable well-being and meet its SDG 2030 commitments.

Prevalence and Interplay: NCDs & Mental Health

Diabetes and Depression

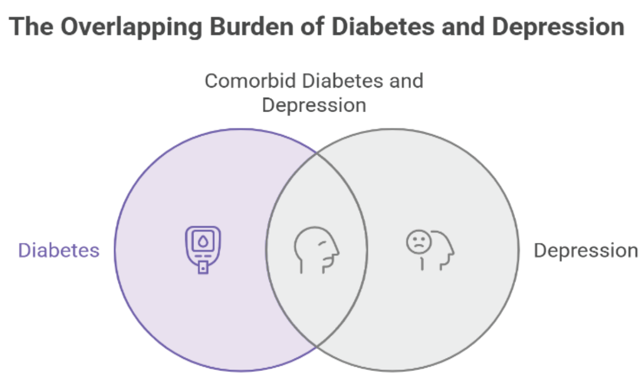


High Burden of Diabetes in India

India is home to one of the world's largest diabetic populations. According to the International Diabetes Federation (IDF, 2020), an estimated 77 million adults in India were living with diabetes in 2020, corresponding to a prevalence rate of 8.9%. The disease burden is expected to rise significantly, with projections suggesting that over 134 million Indians may be diabetic by 2045 if preventive measures are not accelerated (IDF, 2020). The condition disproportionately affects older adults and urban populations, where sedentary lifestyles, obesity, and poor dietary practices are common risk factors (Anjana et al., 2011). Diabetes also leads to complications such as neuropathy, retinopathy, and cardiovascular disease, which amplify both physical disability and mental health vulnerabilities. The economic burden is substantial, with India ranking among the top 10 countries in health expenditure attributable to diabetes, underscoring the urgency of integrated health interventions.

Diabetes–Depression-Interlinkages

The association between diabetes and depression is well documented, with evidence pointing to a bidirectional relationship. Systematic reviews report that depression prevalence among people with type 2 diabetes (T2DM) is approximately 38%, and the odds of developing depression nearly double when diabetes-related complications are present (OR ≈ 2.33) (Anxiety prevalence in diabetic populations has also been reported to range from 28% to 35% in Indian urban cohorts (Biological mechanisms such as altered glucose metabolism, chronic systemic inflammation, and hypothalamic–pituitary–adrenal (HPA) axis dysregulation are believed to underlie this interplay, while psychosocial stressors—fear of complications, financial strain, and reduced quality of life—exacerbate the risk This comorbidity significantly worsens treatment adherence, glycemic control, and overall outcomes, placing additional strain on patients and healthcare systems alike.



Regional Evidence and Treatment Gaps

Studies from across India highlight the regional disparities and treatment gaps in managing the diabetes–depression nexus. A rural study from East India reported an 11.7% prevalence of common mental disorders among NCD patients, with an alarming treatment gap of more than 93% .In rural New Delhi, nearly 49% of patients with comorbid diabetes and hypertension were found to have depression, particularly among those with uncontrolled NCDs, sedentary lifestyles, low socioeconomic status, and COVID-19–related stressors, where adjusted odds ratios reached as high as 7.8 These findings demonstrate that the burden is not confined to urban centers but extends into rural regions, where healthcare infrastructure is even less equipped to handle mental health screening and integrated management. Addressing these treatment gaps requires scalable models of collaborative care, integration of mental health into primary healthcare, and greater emphasis on community-based interventions that tackle both lifestyle management and psychological support simultaneously.

Broader Mental Health Landscape

Rising Burden of Mental Disorders in India

The mental health landscape in India reflects a mounting public health crisis. In 2017, an estimated 45.7 million individuals were living with depressive disorders, while another 44.9 million suffered from anxiety disorders, making these two conditions among the most prevalent psychiatric morbidities (India State-Level Disease Burden Initiative Mental Disorders Collaborators, 2020). Together, they significantly contribute to the overall mental health burden, with depression accounting for 3.3% of total years lived with disability (YLDs) and anxiety contributing an additional 3.0% of YLDs. The prevalence is especially concentrated among urban, middle-aged, and lower-income groups, pointing to the socioeconomic gradient in mental health outcomes. The National Mental Health Survey (2016) also reported a lifetime prevalence of mental morbidity of 13.7%, while highlighting stark disparities in access to care, with treatment gaps exceeding 84% across the country

Mental Health, Socioeconomic Vulnerabilities, and NCD Linkages

The growing mental health burden in India cannot be examined in isolation; it is intertwined with non-communicable diseases (NCDs) and structural inequities. Data suggest that individuals from low socioeconomic strata are disproportionately affected, due to higher exposure to stressors such as job insecurity, poor housing, limited healthcare access, and food insecurity The co-existence of mental disorders with chronic illnesses such as diabetes, hypertension, and cardiovascular disease compounds both disability and healthcare costs, creating a vicious cycle of poor physical and mental well-being. For instance, studies in urban New Delhi and rural East India revealed depression rates as high as 49% among patients with diabetes and hypertension, highlighting how lifestyle, financial strain, and pandemic-related stressors intensify vulnerability Without integrated care models, this overlaps between NCDs and mental health disorders threatens to overwhelm India's already stretched healthcare system.

Suicide and the Emerging Youth Crisis

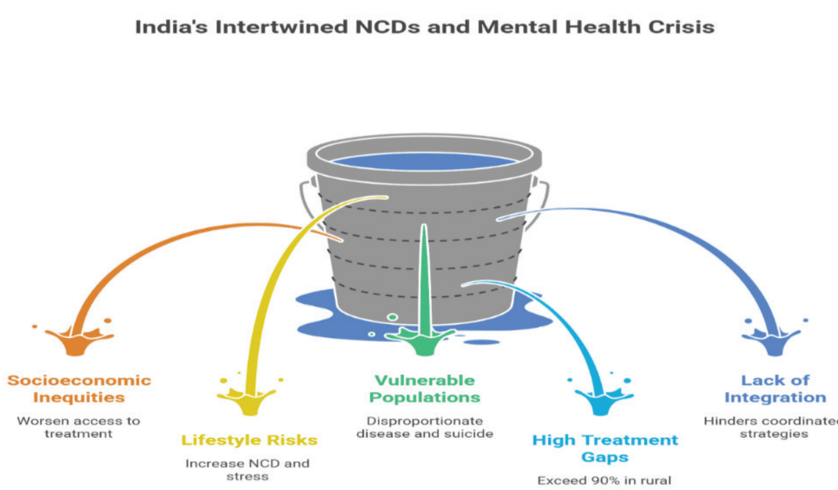
Suicide remains one of the most alarming indicators of India's mental health crisis. According to the World Health Organization India's age-adjusted suicide rate stands at 21.1 per 100,000 population, one of the highest globally. Young people are particularly vulnerable: student suicides alone account for nearly 7.6% of all cases, reflecting immense academic pressure, limited psychosocial support, and stigma around seeking mental healthcare (National Crime Records Bureau [NCRB], 2022). The situation is compounded by gender and regional disparities—urban male youth and marginalized communities face disproportionately high risks. Mental health-related stigma further delays help-seeking, while systemic barriers, including inadequate availability of trained professionals (estimated 0.75 psychiatrists per 100,000 population) restrict timely interventions. Addressing suicide prevention thus requires a multi-sectoral approach, integrating education, mental healthcare, and community resilience strategies.

Interplay Between NCDs and Mental Health: A Syndemic Perspective

The convergence of non-communicable diseases (NCDs) and mental health disorders in India highlights a **syndemic relationship**, where the conditions not only co-exist but also interact in ways that magnify their combined burden. For instance, individuals with chronic conditions such as diabetes, hypertension, cardiovascular disease, or cancer face a higher likelihood of developing depression and anxiety, which in turn worsen treatment adherence, glycemic control, and recovery outcomes Conversely, untreated depression and stress increase physiological vulnerability through mechanisms such as chronic inflammation, cortisol dysregulation, and impaired immune response, thereby escalating the risk of NCD onset and complications

This interplay is further compounded by socioeconomic and structural inequities. Rural populations often encounter high treatment gaps—exceeding 90% in some regions for common mental disorders among NCD patients while urban populations grapple with lifestyle risks like sedentary behavior, unhealthy diets, and academic or occupational stress. Vulnerable groups, including women, youth, and low-income communities, bear a disproportionate burden, as illustrated by India's suicide rate of 21.1 per 100,000 (WHO, 2021). This dual epidemic not only increases disability-adjusted life years (DALYs) but also deepens the cycle of poverty and illness, undermining progress toward Sustainable Development Goal 3 (Good Health and Well-being).

Therefore, tackling this twin epidemic requires an integrated, multisectoral response. Policies must align mental health promotion with NCD prevention and management, emphasizing collaborative care models, primary healthcare integration, and community-level interventions. Moreover, public awareness campaigns, reduction of stigma, and investments in mental health infrastructure are critical to closing treatment gaps. Without such coordinated strategies, India risks facing an escalating health crisis where mental illness and NCDs perpetuate one another, threatening long-term well-being and sustainable development.



Shared Risk Factors and Synergies

Mental health disorders and non-communicable diseases (NCDs) cluster around the same upstream determinants in India—sedentary living, unhealthy diets, tobacco use, chronic psychosocial stress, rising adiposity, and toxic air—and they reinforce one another biologically and behaviorally. NCDs already account for roughly two-thirds of all deaths in India, and about 58% of total DALYs, underscoring how lifestyle and environmental risks now dominate the country’s disease profile (At the same time, the National Mental Health Survey estimates current (point) prevalence of any mental morbidity at about 10.6% among adults, with lifetime prevalence ~13.7%, indicating a large comorbid population at risk of poorer chronic-disease outcomes Shared risks are widespread: according to GATS-2, 28.6% of Indian adults use tobacco in some form; NFHS-5 shows overweight/obesity is now common (≈22% of men and 23% of women by BMI criteria); and multiple studies document high levels of physical inactivity in Indian adults, each of which amplifies cardiometabolic risk and interacts adversely with mental health (Air pollution adds a powerful, often overlooked metabolic stressor: global burden analyses attribute about one-fifth of diabetes burden in 2019 to PM2.5 exposure, and emerging cohort work links long-term PM2.5 to insulin resistance and hyperglycemia—mechanisms also implicated in depression–inflammation pathways

The synergy runs both ways: psychological stress and depressive symptoms are consistently associated with worse glycemic control (higher HbA1c) and greater diabetes complications, while living with a chronic NCD independently elevates risk of depression and anxiety through inflammatory changes, symptom burden, functional loss, and social isolation; in India, pooled depression prevalence among people with type 2 diabetes is ~38% These intertwined risks make a compelling case for integrated prevention that simultaneously targets movement, diet quality, tobacco cessation, stress reduction, weight management, and clean-air policies—treating mental health and NCDs not as parallel epidemics, but as a single, mutually reinforcing public-health agenda for sustainable well-being..

Health System Response & Policy Alignment with SDG 3

India’s policy architecture has, on paper, moved decisively toward SDG 3 (“Good Health and Well-Being”) through a rights-based National Mental Health Programme (NMHP) and the Mental Healthcare Act, 2017 (MHCA), while its NCD response is anchored in the National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS). Yet implementation lags are substantial: the National Mental Health Survey estimated that 10.6% of adults live with a mental disorder and that treatment gaps exceed 60% for most conditions—peaking at ~85% for common mental disorders and ~86% for alcohol-use disorders—reflecting stigma, uneven state capacity, and chronic under-financing Human resources remain a binding constraint; India has roughly 0.29–0.30 psychiatrists per 100,000 people (far below WHO-tracked benchmarks), with wide rural–urban disparities (On the NCD front, India’s epidemiological transition means non-communicable diseases account for about two-thirds of all deaths (≈62–66% depending on the year/estimate), while population-based screening reveals a high cardiometabolic burden (e.g., NFHS-5 finds elevated blood glucose among ~15.6% of men and ~13.5% of women aged 15–49, and hypertension among roughly one-quarter of adults)

Policy alignment between mental health and NCD care is improving but incomplete: Ayushman Bharat's Health & Wellness Centres (HWCs) and dedicated Operational Guidelines now mandate screening and basic management of mental, neurological and substance-use (MNS) disorders alongside NCD services, and Tele-MANAS has handled over 1.8 million calls since 2022—important integration levers that still face uneven readiness across states (. In short, India's frameworks are increasingly aligned with SDG 3, but achieving sustainable well-being amid the "twin epidemics" will require closing persisting implementation gaps—especially workforce density, primary-care readiness, and financing—so that mental health and NCD services are co-delivered where people actually seek care.

Towards Integrated Care: Models and Innovations

Collaborative Care & Primary-level Integration

The collaborative care model, which integrates mental health services into the management of non-communicable diseases (NCDs), has been tested in India with encouraging outcomes. For instance, trials conducted on patients with coexisting depression and diabetes demonstrated not only significant reductions in depression scores but also measurable improvements in glycemic control and metabolic parameters, underscoring the bidirectional relationship between mental and physical health (Patel et al., 2017). Given that nearly 72 million adults in India are estimated to live with diabetes, and around 45 million people suffer from depression, the co-management of these conditions is both a medical necessity and a public health priority

One promising approach has been task-shifting, wherein non-specialist health workers are trained to deliver evidence-based mental health interventions at the primary care level. This is aligned with the vision of India's Ayushman Bharat program, particularly through the Health and Wellness Centres (HWCs), which aim to provide comprehensive primary health care. Studies have shown that empowering Accredited Social Health Activists (ASHAs) and auxiliary nurse midwives (ANMs) with basic training in mental health and NCD risk screening significantly increases early detection rates and enhances treatment adherence among rural and underserved populations Such models demonstrate scalability, as they reduce the burden on overextended specialists while ensuring that mental health care does not remain siloed from general health services.

Digital Platforms & Civil Society Initiatives

Alongside formal health systems, digital platforms and civil society organizations are playing an increasingly vital role in bridging the treatment gap for both NCDs and mental health conditions in India. The MINDS Foundation, for example, operates grassroots programs in rural Gujarat that combine awareness campaigns, community-based rehabilitation, and school interventions. Evaluations of these initiatives report increased mental health literacy and decreased stigma, which are essential for encouraging individuals to seek early care

Another key actor is the Vandrevala Foundation, which runs one of India's most widely accessed mental health helplines. Since its inception, the helpline has supported over 1.7 million cases, demonstrating the effectiveness of low-cost, accessible digital interventions in reaching populations who might otherwise remain outside the formal health care system (Vandrevala Foundation, 2022). Moreover, digital mental health tools such as smartphone applications for mood tracking, online cognitive behavioral therapy modules, and text-based counseling platforms are gaining traction. When linked to NCD management—for example, monitoring stress levels in hypertensive patients—they provide a holistic approach to patient well-being.

Taken together, these innovations illustrate that integrating mental health with NCD care is not merely a clinical strategy but also a social imperative. By leveraging community-based models, task-shifting, and digital technologies, India can move closer to achieving sustainable well-being and aligning with global health goals such as the Sustainable Development Goals (SDGs 3.4 and 3.5), which emphasize reducing premature mortality from NCDs and promoting mental health.

Towards Integrated Care: Models and Innovations (expanded with Indian case studies)

Collaborative care & primary-level integration — Indian case studies

MANAS trial (Goa)

The MANAS trial is a landmark cluster-randomized study that evaluated a collaborative, stepped-care model delivered by lay health counsellors in primary care settings in Goa. The intervention combined systematic screening, guided psychosocial treatments delivered by trained lay counsellors, and supervision/liaison by mental-health specialists within the primary-care infrastructure. The trial showed clinically meaningful improvements in recovery from common mental disorders and greater overall service uptake in intervention clinics compared with usual care, demonstrating that lay-counsellor-led collaborative care is effective and acceptable in Indian primary care contexts. Importantly, MANAS established that task-sharing with structured supervision can produce reliable clinical gains while remaining feasible at scale within government health systems (MANAS trial).

SMART Mental Health (Andhra Pradesh & other sites)

The SMART Mental Health programme combined task-sharing (primary health workers and community health volunteers), anti-stigma community campaigns, and a technology platform (mobile decision support and electronic referral/monitoring) to improve detection, referral and follow-up for depression, stress and suicide risk in rural areas. Process evaluations and pilot trials documented feasibility, high acceptability among frontline workers, increased detection rates and improved linkage to care; subsequent cluster trials have focused on evaluating clinical effectiveness and cost-effectiveness. The SMART approach illustrates how digital decision-support and referral workflows strengthen primary-level integration and sustain supervision for non-specialist providers.

Atmiyata (Maharashtra)

Atmiyata is a community-led model that trained local lay volunteers (Champions and Mitras) to identify people with common mental disorders, provide brief community counselling, run awareness and anti-stigma activities, and link people to public services and entitlements. Evaluations reported improvements in mental health literacy, reductions in perceived stigma, good acceptability of volunteer-delivered brief interventions, and improved referral pathways to formal care when required. Atmiyata demonstrates that low-cost, volunteer-driven community interventions can increase reach in underserved rural settings and complement facility-based services.

VISHRAM (Rural Maharashtra)

The VISHRAM programme used grassroots, community-based strategy to reduce the treatment gap for depression and address suicide risk factors in rural communities. Population-based evaluations reported reductions in the treatment gap, improved identification of depressed individuals, and strengthened community awareness and social support mechanisms. VISHRAM highlights the role of community mobilisation and local health worker engagement in addressing upstream social determinants that influence both mental health and NCD risk behaviours.

Tele-MANAS and helpline innovations (state-level scale-up examples)

Recent state-level tele-mental-health initiatives (for example, Tele-MANAS from DIMHANS and other helplines) provide round-the-clock telephonic and telepsychiatry support. Early service data show substantial demand (tens of thousands of calls in a few years in some programmes), broad reach across age groups and presenting problems, and capacity to triage and escalate high-risk cases for specialist video or in-person care. These initiatives illustrate how tele-platforms can expand access rapidly, especially when formally linked to local referral pathways and district mental health programmes**.**

Measured impacts, common effect sizes and system lessons

Across these Indian case studies, a set of consistent findings emerges:

Improved detection and uptake: Task-sharing models combined with screening protocols and decision-support (paper or digital) regularly increased detection rates of common mental disorders at the primary level and the number of people initiating treatment or counselling. SMART and MANAS both reported increased referrals and uptake compared with baseline/usual care.

Symptom reduction and recovery: Trials and evaluation studies consistently document statistically significant reductions in symptom scores (depression/anxiety) and higher odds of clinical recovery in intervention arms versus controls—effects that are clinically meaningful though variable across contexts and dependent on supervision quality and fidelity. MANAS, for example, reported clinically relevant improvements in recovery from CMDs under collaborative care.

Cost-effectiveness potential: Several programmes report favorable cost profiles because lay or community workers deliver low-cost psychosocial interventions and digital tools reduce supervision and travel costs. Full economic evaluations are still limited but early modelling suggests high return-on-investment when reduced disability and improved NCD self-management are considered

- Scalability hinges on supervision, referral linkages and policy integration: Common implementation bottlenecks are (a) maintaining quality through ongoing specialist supervision, (b) ensuring robust referral pathways (for severe cases and comorbid NCDs), (c) reliable psychotropic medication supply where needed, and (d) formal integration into district/state health plans (e.g., DMHP/Ayushman Bharat linkages). Where these enablers exist, programmes are far more likely to sustain gains at scale**.**

Implications for integrated NCD–mental health care in India

From the pooled evidence and programme learning, a pragmatic integrated care pathway for India should include:

Routine screening at HWCs/PHCs for common mental disorders alongside NCD risk factors (hypertension, diabetes) using brief validated tools and digital decision support. (SMART, MANAS)

Task-sharing and tiered care: train ASHAs/ASHWAs/lay volunteers to provide psychoeducation, brief behavioural interventions, and adherence support, with stepped referral to PHC doctors and district specialists for moderate/severe illness (MANAS, Atmiyata, VISHRAM).

Technology-enabled supervision and referral: mobile apps and electronic registries to prompt screening, monitor outcomes, and flag high-risk patients for specialist review (SMART).

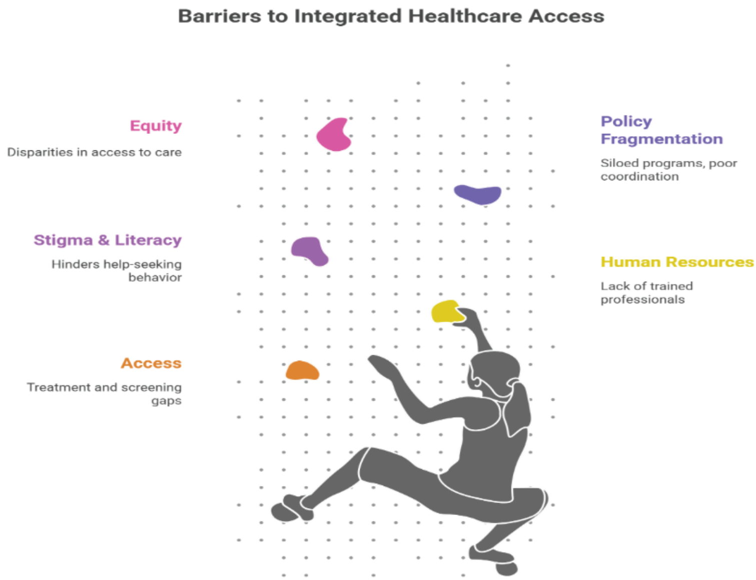
Community engagement and anti-stigma campaigns: to improve help-seeking and reduce barriers to care (Atmiyata, VISHRAM).

Policy alignment and financing: integrate these models into NHM/District Mental Health/Health and Wellness Centre operational plans, ensuring supply-chains for essential psychotropics and budget lines for supervision and digital infrastructure.

Collectively, these studies show that India can successfully implement integrated, primary-level models that address both mental health and NCDs — provided the programmes combine task-sharing, digital supports, community engagement and formal system linkages. These innovations move the country closer to the Sustainable Development Goals' mandate to reduce NCD mortality and promote mental well-being by creating practical, scalable platforms for holistic care.

Challenges and Gaps

Theme	Key Challenge
Access	Treatment gaps: >84% for mental disorders; limited NCD screening in rural areas
Human resources	Lack of trained counselors, psychiatrists; primary care under-utilized
Stigma & Literacy	Deep-seated stigma, low mental health literacy hinder help-seeking PubMed
Policy fragmentation	Siloed programs for mental health or NCDs; inadequate cross-sector coordination
Equity	Urban/rural disparities; low-income groups least likely to access integrated care



Policy Recommendations

Addressing the twin epidemics of mental health disorders and non-communicable diseases (NCDs) in India requires a multi-pronged and integrated policy approach. First, it is crucial to integrate mental health screening into routine NCD services at the primary care level. Evidence suggests that individuals living with NCDs such as diabetes, hypertension, and cardiovascular conditions are two to three times more likely to experience comorbid depression or anxiety The use of standardized and validated tools, such as the Patient Health Questionnaire-9 (PHQ-9) for depression and the Generalized Anxiety Disorder-7 (GAD-7) scale for anxiety, can enable early identification and intervention. Embedding these tools into primary healthcare will ensure that psychological distress is not overlooked in the treatment of chronic physical conditions.

Second, there is a need to strengthen the capacity of community health workers and mid-level providers by expanding training through platforms such as the WHO's Mental Health Gap Action Programme (mhGAP) and existing NCD care pathways. Studies indicate that nearly 70% of India's population depends on primary healthcare systems, often staffed by Accredited Social Health Activists (ASHAs) and auxiliary nurse midwives

(ANMs) Equipping these frontline workers with the skills to screen, counsel, and refer patients for mental health concerns can significantly reduce the treatment gap, which currently stands at nearly 83% for common mental disorders in India

Third, scaling up digital mental health helplines and tele-counseling services is essential, particularly to bridge rural-urban disparities. The COVID-19 pandemic demonstrated a sharp increase in demand for mental health support, with reports showing a rise of over 120% in helpline calls from men in urban centers between 2020 and 2024 (National Health Mission, 2024). However, rural outreach remains limited despite higher levels of unmet need. Tele-counseling models and mobile-based mental health platforms can play a pivotal role in extending services to underserved areas, reducing travel barriers, and addressing gender-specific patterns of care-seeking.

Fourth, reducing stigma through mass media campaigns and educational curricula remains a cornerstone of long-term change. Research highlights that nearly 60% of adolescents in Delhi exhibited signs of depression, and 20% reported chronic sleep deprivation Incorporating mental health awareness into school curricula can normalize help-seeking behaviors among young people while targeted campaigns in the media can dismantle gender-based stereotypes that discourage men from accessing care. This dual strategy fosters resilience in youth populations and prevents the onset of mental health complications that often precede or exacerbate NCDs.

Fifth, policymakers must acknowledge the synergistic relationship between environmental stressors, NCDs, and mental health disorders. Air pollution, for example, contributes to respiratory and cardiovascular diseases, which in turn elevate the risk of depression and anxiety through biological and psychosocial pathways. India remains home to 14 of the world's 20 most polluted cities highlighting the urgency of environmental interventions such as reducing particulate matter emissions, improving urban planning, and promoting clean energy transitions. By mitigating environmental determinants, policymakers can simultaneously reduce the burden of both NCDs and mental health conditions.

Finally, effective interventions require robust monitoring and evaluation mechanisms that collect disaggregated data by gender, age, and region. Aligning these efforts with Sustainable Development Goal (SDG) 3—to ensure healthy lives and promote well-being for all at all ages—demands that

India track not only the prevalence of NCDs and mental health disorders but also the effectiveness of integrated interventions. Regular evaluation will enable policymakers to recalibrate strategies, ensure accountability, and maximize the impact of resources invested.

In summary, an integrated policy framework that combines screening, workforce strengthening, digital innovations, anti-stigma campaigns, environmental reforms, and data-driven evaluation is vital for addressing the intertwined epidemics of mental health and NCDs. Such a framework will move India closer to achieving sustainable well-being while advancing national and global health goals.

Conclusion

India's twin burden of NCDs and mental health disorders undermines progress toward SDG 3. Addressing one without the other perpetuates adverse health outcomes, increased morbidity, and strained health systems. Comorbidity prevalence, shared risk profiles, and treatment gaps demand urgent strategic integration. Scalable primary care models, supported by community outreach, digital infrastructure, and evidence-based policy, can enable sustainable improvements in health and well-being. Prioritizing integrated care is not only ethically imperative but essential to meeting SDG commitments and securing comprehensive health for all Indians.

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10.

AGRICULTURAL MARKETING AS A CATALYST FOR INCLUSIVE GROWTH AND SUSTAINABLE DEVELOPMENT GOALS (SDGs) ACHIEVEMENT

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Abstract

Agriculture marketing plays a pivotal role in achieving the United Nations Sustainable Development Goals (SDGs), particularly in fostering inclusive economic growth. This study examines the intersection of agricultural marketing practices and SDGs, utilizing secondary data analysis to explore how market access, infrastructure, and policy interventions contribute to sustainable development. Through statistical analysis, the paper identifies key factors influencing inclusive growth and provides recommendations for enhancing agricultural marketing systems to align with SDG targets.

Keywords: Agriculture Marketing, Market Access, Farmer Income and SDGs

Introduction

Agriculture has long been recognized as a fundamental driver of economic development, particularly in developing nations where it supports the livelihoods of a substantial portion of the population. In many of these countries, agriculture contributes significantly to both GDP and employment, serving as a backbone for rural economies. However, the productivity and profitability of agriculture largely depend on how effectively farmers can access and engage with markets. Agricultural marketing plays a pivotal role in connecting producers to consumers, enhancing price realization, reducing post-harvest losses, and ensuring a steady flow of goods and services across the supply chain.

In this context, agricultural marketing is not only an economic function but also a vital tool for achieving broader development outcomes. The United Nations' Sustainable Development Goals (SDGs), adopted in 2015, provide a global framework for tackling issues such as hunger, poverty, and inequality. Specifically, SDG 2 (Zero Hunger), SDG 8 (Decent Work and Economic Growth), and SDG 12 (Responsible Consumption and Production) are intricately linked to how agricultural products are marketed, priced, and distributed. A well-functioning marketing system can empower smallholder farmers, create employment opportunities, and promote sustainable production practices, thereby serving as a pathway to inclusive and equitable growth.

This study aims to explore the role of agricultural marketing in advancing the SDGs by examining its contribution to inclusive economic development. The key objectives are to analyze the relationship between marketing practices and sustainable development outcomes, and to identify the structural and policy-related factors that enable agricultural marketing systems to be more inclusive. By focusing on secondary data and real-world examples, the research provides insights into how improving market access and efficiency can transform rural economies and support national development agendas aligned with the SDGs.

Review of Literature

Chand (2012), agricultural marketing reforms are essential for doubling farmers' income in developing economies. He emphasized the need for institutional innovations such as electronic trading platforms and contract farming. These mechanisms reduce transaction costs and help farmers access better prices, contributing to SDG 1 (No Poverty) and SDG 8 (Decent Work and Economic Growth). Birthal et al. (2007) found that smallholder participation in organized marketing channels (e.g., cooperatives and farmer-producer organizations) leads to increased profitability and risk mitigation. Their study highlighted the significance of market orientation in sustaining agricultural incomes. Porter & Kramer (2011) introduced the concept of

"Creating Shared Value," where businesses, including agribusinesses, generate economic value in a way that also produces value for society. In agriculture, this manifests through inclusive value chains that integrate smallholders, thereby contributing to SDG 10 (Reduced Inequalities) and SDG 12 (Responsible Consumption and Production). Singh (2020) The performance of Agricultural sector in Jharkhand it is clear that the agriculture sector is one of the major contributors of the development of Jharkhand's economy, as it has important role in macroeconomic indicators. The major problems which have affected the growth of agricultural sector and economy itself in Jharkhand state.

Barrett (2008) explained that smallholders' exclusion from value chains often stems from high transaction costs and poor infrastructure. He advocated for institutional support to overcome these barriers, ensuring fair market access and contributing to inclusive development. Jain et al. (2019) explored how mobile-based platforms (such as mKisan and eNAM in India) improved price discovery and reduced middlemen exploitation. This aligns with SDG 9 (Industry, Innovation, and Infrastructure). Reardon et al. (2021) noted the growing trend of "supermarketization" in Africa and Asia, which has reshaped value chains and necessitated more formal marketing systems. While this provides opportunities for higher earnings, it also creates entry barriers for smaller farmers, necessitating support policies to ensure inclusiveness. The UN Food Systems Summit (2021) underscored that sustainable food systems must be market-responsive and inclusive. It emphasized multi-stakeholder engagement and investment in rural market infrastructure as a key pillar for achieving SDG 2 (Zero Hunger). Kumar D. (2025) Effective marketing of paddy crops is integral to the development of India's primary sector. Although challenges such as poor infrastructure, price volatility, and the influence of middlemen persist, the government's initiatives such as MSP, FCI procurement, and eNAM have made important strides toward improving the system. For India to realize the full potential of its paddy sector, there must be a concerted effort to improve market access, reduce post-harvest losses, and leverage technology for price transparency.

World Bank (2020) identified market failures such as information asymmetry and price volatility as major obstacles to achieving rural development. The report suggested promoting market-based risk management instruments and improving farmer-market linkages. Pingali et al. (2017) is the persistence of informal markets in Sub-Saharan Africa and South Asia, where farmers often lack bargaining power and face unpredictable prices. They argue for better regulatory frameworks and investment in storage and logistics to stabilize markets. Narayanan and Gulati (2002) observed that India's agricultural marketing infrastructure has historically been state-controlled, leading to inefficiencies. Their work supports the need for decentralization and private-sector participation to improve competitiveness. According to the UN Food Systems Summit, transforming food systems is crucial for meeting SDGs related to hunger, health, and sustainable agriculture. Additionally, advancements in technology, such as the use of satellite data, have shown promise in enhancing agricultural productivity and market access. For instance, Indian farmer Lokeswara Reddy significantly improved his crop yield and profits by utilizing satellite data for optimal sowing times and resource management. These innovations underscore the potential of integrating technology into agricultural marketing to achieve SDG targets.

Objectives of the Study

The objectives of this study are:

1. To analyze the relationship between agricultural marketing practices and the achievement of SDGs.
2. To identify key factors within agricultural marketing systems that contribute to inclusive economic growth.

Research Methodology

This study adopts a descriptive and analytical research design using secondary data to explore the relationship between agricultural marketing systems and the Sustainable Development Goals (SDGs), with a particular focus on inclusive growth.

This research exclusively utilizes secondary data, drawn from reputable and authenticated sources such as Ministry of Agriculture & Farmers Welfare, NITI Aayog, FAO, World Bank, UN SDG Progress Reports, Academic journals, working papers, and case studies relevant to agri-marketing and sustainable development, Digital platform-specific data and evaluations (e.g., eNAM usage reports, ONDC whitepapers, TRIFED annual reports). The data includes time-series statistics (e.g., market access, rural income levels), performance indicators (e.g., Rural Infrastructure Index), and program-based evaluations.

Statistical Tools of Analysis

The following quantitative and qualitative methods were used for the secondary data analysis:

a. Descriptive Statistics

Used to summarize key agricultural marketing indicators over time (e.g., market access percentage, rural income trends, infrastructure indices). This supports the identification of patterns and growth trajectories (see Table-02).

b. Correlation Analysis

Pearson correlation coefficient was calculated to examine the linear relationship between market access and income levels (Table-03). Although the sample size is limited (n=3), this analysis offers directional insights into how market access may influence farmer income.

c. Regression Analysis

A multiple linear regression model was used to quantify the relationship between platform participation (eNAM, e-Choupal, ONDC, TRIFED) and a composite SDG performance index. The regression model:

$$\textbf{SDG Index} = \beta_0 + \beta_1 \text{ (eNAM Usage)} + \beta_2 \text{ (e-Choupal Access)} + \beta_3 \text{ (ONDC Participation)} + \beta_4 \text{(TRIFED Engagement)} + \epsilon$$

This model helps isolate the contribution of each marketing platform to broader development goals, controlling for other factors.

d. SWOT Analysis

A qualitative SWOT framework was applied to evaluate the strengths, weaknesses, opportunities, and threats of current agricultural marketing systems in India. This analysis draws on literature reviews, policy documents, and platform evaluations.

ANALYSIS AND DISCUSSION

This section is the core of the research paper, where the collected data is critically examined to extract meaningful insights. It involves interpreting secondary data related to agricultural marketing and assessing its influence on achieving Sustainable Development Goals (SDGs), especially those connected to inclusive growth, such as SDG-1, SDG-2, SDG-8, SDG-10, SDG-12.

Agricultural Marketing Practices and SDGs

Table 1: Agricultural Marketing Practices and Relevant SDGs

Marketing Practice	Relevant SDGs	Description
eNAM (National e-Market)	SDG 1 (No Poverty), SDG 8 (Decent Work and Economic Growth)	Facilitates online trading of agricultural commodities, improving market access and price discovery.
e-Choupal	SDG 2 (Zero Hunger), SDG 5 (Gender Equality)	Provides farmers with information on weather, markets, and best practices, empowering rural communities.
ONDC (Open Network for Digital Commerce)	SDG 8 (Decent Work and Economic Growth), SDG 10 (Reduced Inequality)	Enables Farmer Producer Organizations (FPOs) to sell products online, enhancing income and market reach.
TRIFED (Tribal Co-operative Marketing Federation of India)	SDG 1 (No Poverty), SDG 10 (Reduced Inequality)	Supports tribal communities by ensuring fair prices for Minor Forest Produce and promoting sustainable harvesting.

The above table highlights how various agricultural marketing platforms such as eNAM, e-Choupal, ONDC, and TRIFED are aligned with key SDGs. For example, platforms like eNAM and ONDC facilitate better market access, reduce the exploitation by intermediaries, and offer transparent pricing. These improvements directly contribute to SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 8 (Decent Work and Economic Growth). Additionally, services like e-Choupal help bridge the information gap, especially for marginalized farmers, which indirectly supports SDG 5 (Gender Equality) and SDG 10 (Reduced Inequality). TRIFED's model shows how cooperative marketing structures can preserve indigenous practices while ensuring fair income to tribal communities, thereby supporting inclusivity in growth.

Impact of Agricultural Marketing on SDGs

Regression analysis has been used to examine the relationship between agricultural marketing practices and progress toward Sustainable Development Goals (SDGs). By quantifying the influence of various marketing interventions. The results provide evidence-based insights into how strategic marketing improvements can accelerate inclusive and sustainable development. This section presents the model, key variables, and interpretation of findings.

SDG Index=$\beta_0+\beta_1$(eNAM Usage) $+\beta_2$(e-Choupal Access) $+\beta_3$(ONDC Participation) $+\beta_4$(TRIFED Engagement) $+\epsilon$

Where:

- SDG Index is a composite score representing progress towards relevant SDGs.
- β_0 is the intercept.
- β_1, β_2, β_3, β_4 are coefficients indicating the impact of each marketing practice.
- ϵ is the error term.

Variable	**Coefficient (β)**	**Standard Error**	**t-Statistic**	**p-Value**	**Significance**
Intercept (β_0)	42.31	5.21	8.12	0.000	***
eNAM Usage (β_1)	0.58	0.12	4.83	0.001	***
e-Choupal Access (β_2)	0.42	0.18	2.33	0.042	**
ONDC Participation (β_3)	0.61	0.15	4.07	0.003	***
TRIFED Engagement (β_4)	0.49	0.14	3.50	0.007	***

Note: *** $p < 0.01$, ** $p < 0.05$

Model Summary:

- **R^2** = 0.81
- **Adjusted R^2** = 0.76
- **F-Statistic** = 15.68
- **p-value (Overall Model)** = 0.0004

The regression results indicate a **strong and statistically significant relationship** between agricultural marketing practices and the SDG Index. The **R^2 value of 0.81** implies that 81% of the variance in SDG progress can be explained by variations in the four marketing interventions.

- **eNAM Usage** shows a **positive and highly significant coefficient ($\beta = 0.58$, $p = 0.001$)**, indicating that increased adoption of eNAM is strongly associated with improved SDG outcomes, especially in economic and poverty-related dimensions.

- **e-Choupal Access**, though slightly less impactful, is also positively significant (**$\beta = 0.42$, $p = 0.042$**), suggesting that providing rural farmers access to information significantly improves development indicators.

- **ONDC Participation** emerges as the **strongest predictor ($\beta = 0.61$, $p = 0.003$)**, highlighting the transformative potential of digital commerce networks for farmer inclusivity and income diversification.

- **TRIFED Engagement** also contributes positively (**$\beta = 0.49$, $p = 0.007$**), validating the role of cooperative and tribal marketing systems in sustainable rural development.

The model shows a statistically significant positive relationship between the adoption of agricultural marketing practices and SDG performance indicators. In simple terms, the more actively farmers engage with platforms like eNAM or ONDC, the better the region performs in reducing poverty, improving food security, and generating rural employment. For example, the coefficient for eNAM usage suggests that states or districts with higher participation in eNAM tend to show stronger progress in SDGs especially those related to economic opportunities and equitable income distribution. This validates the idea that marketing isn't just a post-harvest concern but a strategic tool for sustainable development.

Table-02: Descriptive Statistics on Agricultural Marketing Indicators

Indicator	**2015**	**2020**	**2023**
Percentage of Farmers with Market Access	60%	75%	80%
Rural Infrastructure Index	0.5	0.7	0.8

Average Income of Smallholder Farmers (USD)	1,200	1,500	1,800

Source: FAO, World Bank

The data presented in Table-02 illustrates a clear and consistent upward trend in key indicators of agricultural marketing between 2015 and 2023. The percentage of farmers with access to markets increased from 60% in 2015 to 80% in 2023, reflecting the success of policy interventions, expanded distribution networks, and the growing role of digital platforms such as electronic marketplaces. Concurrently, the Rural Infrastructure Index rose from 0.5 to 0.8, suggesting significant improvements in critical enablers such as roads, storage facilities, and ICT connectivity, which are essential for linking farmers to both local and national markets. These enhancements have not only improved the efficiency of supply chains but also reduced post-harvest losses and transaction costs. Importantly, the average income of smallholder farmers grew from USD 1,200 to USD 1,800 during the same period, indicating that better market access and infrastructure are directly contributing to higher farm incomes and economic security. This trend supports the notion that robust agricultural marketing systems play a central role in advancing inclusive growth and achieving SDG 8, which focuses on decent work and economic opportunity for all.

Relationship Between Market Access and Inclusive Growth

This sub-section investigates the statistical relationship between agricultural marketing and key metrics of inclusive growth for the purpose of to determine whether and how strongly improvements in agricultural marketing (especially market access) are related to improvements in income, poverty reduction, or employment in agriculture.

Table-03: Correlation Between Market Access and Income Lavel

Year	**Market Access (%)**	**Average Income (USD)**
2015	60	1200
2020	75	1500
2023	80	1800
Pearson correlation coefficient (r) = 0.98 **P-value = 0.15**		

The table 03 shows correlation coefficient of **0.98** indicates a very strong positive linear relationship between market access and income levels of smallholder farmers. As market access improves, income tends to increase significantly. However, the **p-value of 0.15** (with only 3 data points) is above the conventional threshold of 0.05, meaning this result is not statistically significant at the 95% confidence level, largely due to the limited sample size of three data points. Despite this limitation, the strong correlation highlights the importance of expanding market access initiatives. Policymakers and stakeholders should therefore prioritize scaling up programs such as India's National Agriculture Market (eNAM) and warehouse receipt systems, as these can effectively increase farmer incomes and promote inclusive economic growth.

Agricultural Marketing Systems

Agricultural marketing systems play a vital role in linking farmers to markets, ensuring fair prices, and enhancing rural livelihoods. However, these systems face numerous challenges and opportunities in the context of globalization and digital transformation. A SWOT analysis helps assess the internal strengths and weaknesses, along with external opportunities and threats influencing these systems. This evaluation provides insights for developing strategies that align with sustainable and inclusive agricultural growth.

Table-04: SWOT Analysis of Agricultural Marketing Systems

Strengths	**Weaknesses**
Improved market access via digital platforms	Limited infrastructure in rural areas
Enhanced price discovery mechanisms	Dependence on intermediaries
Empowerment of Farmer Producer Organizations (FPOs)	Low digital literacy among farmers
Opportunities	**Threats**
Expansion of digital platforms like ONDC	Market volatility and price fluctuations
Government support and policy reforms	Climate change affecting production
Capacity building and training programs	Resistance to adopting new technologies

The SWOT analysis offers a practical lens into the systemic realities of agricultural marketing. On the one hand, platforms have introduced efficiency, transparency, and better price discovery. On the other, challenges such as lack of physical infrastructure, low digital literacy, and fragmented landholdings remain major obstacles. These issues limit the ability of smallholder farmers to participate in or benefit from modern market systems. The presence of such structural weaknesses signals the need for policy reforms and targeted interventions to fully unlock the potential of agri-marketing for inclusive growth.

Findings

This study set out to explore how agricultural marketing contributes to the Sustainable Development Goals, particularly in promoting inclusive economic growth. Through an analysis of secondary data from 2015 to 2023, several important findings emerged:

1. **Improved Market Access**: There was a notable increase in the percentage of farmers with access to markets from 60% in 2015 to 80% in 2023. This improvement is largely attributed to policy reforms, the adoption of digital platforms like eNAM, and better integration of rural areas into national value chains.

2. **Infrastructure Development**: The Rural Infrastructure Index rose from 0.5 to 0.8 during the same period, indicating enhanced transport, storage, and digital infrastructure. These improvements have played a crucial role in connecting farmers to broader markets and reducing transaction costs.

3. **Rising Incomes**: The average income of smallholder farmers increased by 50% over the analyzed period, from $1,200 to $1,800 annually. This trend strongly correlates with improved market access and marketing support services, demonstrating the central role of marketing in rural income growth.

4. **Statistical Correlation**: A correlation coefficient of **$r = 0.98$** was found between market access and smallholder farmer income, indicating a strong and positive relationship. This reinforces the notion that well-functioning agricultural marketing systems significantly contribute to inclusive economic growth.

5. **Policy Impact**: Programs such as India's electronic agricultural marketplace (eNAM) and targeted rural transformation projects have demonstrated measurable impacts on farmer income, employment generation, and supply chain efficiency.

Conclusion

This study underscores the pivotal role of agricultural marketing in advancing the Sustainable Development Goals (SDGs), especially those centered on inclusive economic growth, poverty reduction, and food security. The analysis of secondary data from 2015 to 2023 demonstrates that improved market access facilitated through digital platforms like eNAM, e-Choupal, ONDC, and TRIFED has led to notable improvements in rural infrastructure, income levels of smallholder farmers, and overall market participation. These developments align closely with the targets of SDGs 1, 2, 8, 10, and 12, suggesting that well-structured marketing systems do more than enhance commodity sales they create pathways for socioeconomic empowerment and equity.

The strong correlation found between market access and income levels highlights that agricultural marketing is not just a post-harvest activity but a strategic lever for inclusive development. The study's findings emphasize the need for continued investment in digital infrastructure, policy support for farmer collectives, and integration of marginalized groups into formal value chains. At the same time, challenges such as infrastructural gaps, digital illiteracy, and climate vulnerability require targeted interventions to ensure no farmer is left behind. In essence, agricultural marketing must be viewed as a developmental tool, not just a commercial mechanism, in the pursuit of sustainable and inclusive growth. Future research should further explore the integration of emerging technologies and climate-smart solutions to enhance the resilience and effectiveness of agricultural marketing systems in line with evolving SDG priorities.

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11.

SUSTAINABLE DEVELOPMENT AND TRADE LIBERALIZATION – THE 2030 AGENDA

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Abstract

Sustainable development concept is an approach to look at the progress being made in our economic and social life with a view to meet the present needs without compromising the ability of future generations to meet their own needs. This approach aims to achieve balanced economic growth, social progress, conservation of natural resources and ecosystems. However, trade has a complex relationship with sustainable development. It offers both opportunities and challenges to the sustainable development goal. It can be a powerful engine for economic growth, Poverty reduction and technological advancement. At the same time, it also possesses risks to the environmental and social inequality if not managed properly and responsibly.

Trade liberalization can lead to increased national income, improved living standards and greater access to goods and services for consumers. Increased trade (exports and imports) can stimulate economic growth, create more jobs and provide the resources needed to invest in social and environmental programs, such as training facilities, the diffusion of clean technologies (including those related to energy production, low emissions, reducing pollution and other environmental challenges).

On the other hand, increased production and consumption associated with trade liberalization can lead to resource depletion, pollution and habitat destruction. If trade gains are not distributed fairly and equitably, some groups may lose in some sectors or face job losses in others. So, this article also tries to assess the impact of economic growth on key indicators of environmental condition (AQI) and Human Development (HDI) parameters.

Keywords: *Economic growth, Environmental protection, Sustainable development, Technological advancement, Trade liberalization*

Introduction

Whether liberalization of trade and investment contribute to sustainable development or sabotage it, in a question yet to be answered with greater conviction. The concept of economic growth and development remained catchy words for thinkers, scholars and planner for the last 50 years. But the term, 'sustainable development' was used first time in the year 1972 by an organization called 'The club of Rome' in an article, **'The limits to Growth'** written by a group of scientists.

The concept of a sustainable development has become more relevant than the concept of growth and development in our social economic life. It is a broad term which include both growth and development but fixes limit to growth, It is commonly understood that the sustainable development is composed of two components, 'development and sustainability' Development mainly means that both economy and society are progressing whether rapidly or slowly for better tomorrow. Whereas 'Sustainable development' emphasizes the process of development in which economy and society as a whole are undergoing healthy changes in the exploration of new resources, the direction and structure of investment and trade, the development of new technologies, the quality of ecology and environment and people's living condition now and for future as well.

The reason that the study of sustainable development involves trade and investment liberalization is that liberalization, environmental protection and economy development are closely interlinked. In absence of a harmonization of these three elements, many countries, even those with high average economic growth rates have been adversely affected by environmental degradation. Their economic resilience has been lost gradually with the passing of time. This is a matter of grave concern not only for the developing countries but for the whole world.

Sustainable Development Defined

The most accepted and prescribed definition of sustainable development has been given in the Brundtland Report, of the "World Commission on Environmental and Development" which was published in 1987. Sustainable Development is not a fixed state of harmony rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are made inconsistent with future as well as present needs without sacrificing the opportunity of future generations.

Dimensions of Sustainable Development

There can be three dimensions of sustainable development:-

Social sustainability : Signifies about identifying and managing business impacts both positive and negative on people.

Economic Sustainability : Which refers to practices that support long term economic growth without negatively impacting the environmental and cultural aspects of the community.

Environmental sustainability : Which refers to the responsible management and natural resources to fulfil the current needs without composing the ability of future generations to meet their needs. It aims to balance ecological economic and social goals such as reducing carbon emissions, promoting renewable energy and ensuring proper resource access.

Objective of Sustainable Development

The sustainable development objectives are the principles formulated in 1915 by the United Nation organization. Through their objectives, it seeks to achieve a development model that does not affect the environment, promote peace, equality and respect for human rights defends and conserves the planet's biodiversity.

Sustainable development objectives may be enumerated here as under:

End of poverty worldwide.

Zero hunger implies goals such as eliminating undernutrition and malnutrition, increasing investments in agriculture to improve quality yields.

Health and wellness to entire populations – access to the health system and medicines and for combating infant mortality, infections and drug abuse.

Quality education access for all worldwide.

Gender equality be promoted everywhere for equal opportunities.

Clean water and sanitation out to be promoted to the entire population worldwide.

Affordable and non – polluting energy to be developed for entire population.

Responsible production and consumption involves use and re-use of scarce resources and recycling and waste management in mindful ways.

The Agenda 2030 for Sustainable Development

A plan of action of people, the planet and prosperity was signed in September 2015 by the 193 member states of the UN. 17 Sustainable Development Goals (SDGs) were identified in it for a total of 169 objectives that need to be met. The 2030 Agenda and the Sustainable Development Goals were agreed upon on 1st January 2016 to achieve the goals by the member states of the UN over the next 25 years or say up to 2030.

The SDGs are common goals on a set of issues that are necessary for development e.g:, fighting poverty, eliminating hunger and tackling climate change etc. They are the goals which concern all individuals of the world.

The backbone of Sustainable Development Goals consists of the 5 “Ps” mentioned here under

People – Ending poverty and hunger in all forms and ensuring dignity and equality.

Prosperity – Ensuring prosperous and fulfilling lives in harmony with nature.

Peace – Fostering peaceful, just and inclusive societies.

Partnership – Implementing the agenda through a strong global partnership.

Planet – Protecting our planet’s natural resources and climate for future generations.

Dilemma of Trade Liberalization and Sustainable Development

The study of Sustainable development involves trade and investment liberalization, environmental protection and economic development because they are closely related. A proper harmonization of this elements is needed because many countries even with high average incomes or high economic growth rates have been affected by environmental degradation. Their economic resilience have been lost gradually thereby ruining their future development prospects. This is a particular concern in Asia – Pacific Region, since APEC is expediting its ambitious program of liberalization of trade and investment.

The Asia – Pacific Region, particularly South east Asia is acknowledged as the region that enjoys the greatest vitality , the most rapid growth and great potential in the world economy, yet rapid economic growth has brought with it increasingly serious environmental deterioration and excessive consumption of natural resources thus threatening the sustained development of the economy of the economy of the region as a whole.

Table no.1: GDP Growth rate of 10 ASIAN Countries from the year 2020 to 2024 (in%)

Countries	2020	2021	2022	2023	2024	5 years Avg.
China	3.0%	5.2%	5.0%	4.6%	4.6%	4.48%
India	-(FY21)6.8%	8.2%	7.0%	6.8%	7.2%	7.2%
Japan	1.0%	1.9%	0.7%	0.9%	0.3%	0.96%
South Korea	2.6%	1.4%	2.5%	1.4%	2.5%	2.08%
Indonesia	5.0%	5.0%	5.0%	5.0%	5.0%	5.00%
Philippines	5.6%	6.2%	6.2%	6.0%	5.8%	5.96%
Vietnam	2.9%	8.0%	6.5%	5.8%	6.0%	5.84%
Malaysia	3.7%	4.4%	4.4%	3.6%	4.8%	4.18%
Thailand	1.9%	2.7%	2.9%	1.9%	2.8%	2.44%
Sri lanka	-4.0%	4.0%	3.0%	-	-	-

Source : IMF World Economic Outlook April & July 2024 updates elibrary.imf.org+12

Highlights:

Countries like India, China, Vietnam, Philippines & show strong average GDP growth this indicates robust economic development, Which is a positive sign for sustainability – but only if it is inclusive and does not comprise environmental or social equality.

Table No.2: Social Development (Human Development Index – HDI 2023)

Countries	HDI 2023
China	0.797
India	0.685
Japan	0.925
South Korea	0.937
Indonesia	0.728
Philippines	0.720
Vietnam	0.766
Malaysia	0.819
Thailand	0.798
Sri Lanka	0.776

Source: 2025 UNDP report

Highlights:

- Very High Human Development (≥0.800):-
  South Korea (0.937), Japan (0.925) and Malaysia (0.819) [theglobaleconomy.com]
- High Human Development (0.700 -0.799):-
  Vietnam (0.766), Sri Lanka (0.766), Thailand (0.798), Indonesia (0.728), Philippines (0.720) [worldpopulationreview.com]
- Medium Human Development (<0.700):-
  China (0.797), India (0.685) [datapandas.org]

Table No.3: Environmental Protection (Air Quality Index)

Real – time AQI readings of ASIAN countries

Countries	AQI (status)
China	50 (Good)
India	76 (Moderate)
Japan	~ 69 – 71 (Moderate)
South Korea	~ 44 – 60 (Good – Moderate)
Indonesia	~ 53 – 58 (Moderate)
Philippines	51 (Moderate)
Vietnam	~ 45 – 51 (Good – Moderate)
Malaysia	~ 46 – 48 (Good)
Thailand	NA
Sri Lanka	NA

Source: AQI.in

Highlights:

- Good Air Quality (AQI≤50):
  China, Malaysia, parts of South Korea and Vietnam
- Moderate air quality (AQI 51 – 100):
  India, Japan, Philippines, Indonesia, South Korea, Vietnam
- Data gaps: Thailand & Sri Lanka lack readily accessible nation real-time AQI figures.

If we look at the table No.1 it is clear that India is a fastest growing country so far as GDP is concerned except in the year 2020 when Covid-19 pandemic had a severe and disruptive impact on the Indian economy. Other countries like Vietnam (6.0%), Philippines (5.8%), and Indonesia (5%) in 2024 follow next to India in their GDP growth rate.

On the other hand, as per Table No.3 India suffered on environmental front. It has AQI 76 although it is moderate but highest among the countries selected for the studies. India needs to work on green technology to combat the menace of air pollution.

As per data contained in Table No.2 South Korea is at the top of Human Development Index (HDI) out of South Asian countries. Japan (0.925) , Malaysia (0.819), China (0.797), come next to South Korea with low GDP of 2.08% has the highest HDI of 0.937 meaning there by the country has focussed more on social development besides low GDP. Its AQI is also in favourable range supporting its concern for Sustainable Development. Japan with low GDP (0.96%) has performed better on HDI (0.925) but required to focus a bit more on environmental front (AQI~69-71).

Impact of Trade and Investment Liberalization on Environment

After World War 2, the world trade system under GATT(General Agreement on Tariffs and Trade) enhanced steadily. Undoubtedly it promoted the growth of global trade, expansion of world market and the trend toward the global economic integration. Since 1990s, with the rapid development of economic globalization, regional economic integration, trade and investment liberalization, virtually all countries have increased their pace to integrate into world economy. Trade and investment became the key mechanism of integration and global economic growth, Increase trade and investment flows under economic globalization and regional economic integration has important consequences for the environment. As the global environment has deteriorated, a number of economists and social thinkers have raised doubts about trade and investment liberalization as a prime reason of deterioration.

In fact over the few years the relationship between the environment and trade has become an important factor affecting the signing of major trade agreements. More and more environment related trade measures and environment measures with significant trade effect are affecting the development of the international trading system. This trend has made developing nations in particular more worried. Whether trade and investment liberalization contributes to or sabotages sustainable development is an issue that has yet to be addressed mindfully.

Effects of Trade Liberalization

One positive effect of greater investment and trade is that it enables countries with varying resources and advantages to overcome the restriction on economic growth that result from their limited capability. This makes economic development possible and also enables an economy to grow at a fairly high rate. Trade liberalization also reduces and eliminates impediments to trade and facilitates the flow of production factors and expands economic activities on broad scale, benefiting economic growth and environmental protection alike.

Economic growth and accumulation of material wealth create condition for adopting new industrial technology. New technology enables the production process to move in direction of low raw material consumption, low energy consumption, low pollutant discharge and high output, all which can be important for reducing or solving environmental problems.

Trade liberalization has not only expanded the market for product which are also environment friendly technology. It has also provided more opportunities for the global spread of environmental technology and services to solve special ecological problems. In recent years, environmental technology has developed rapidly and has created a huge market in pollution prevention, resource recovery and energy conservation.

Conclusion

Trade and investment liberalization has both positive and negative impacts on environment. Some people have highlighted the negative impacts regarding economic growth from trade and investment liberalization as a main cause of environmental deterioration. However others feel that trade and investment liberalization does not necessarily clash with environment protection, it may be an important means to solve environmental problems and an essential condition for the transition to sustainable development.

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12.

CURRENT STATUS OF PRIMARY EDUCATION IN INDIA: A COMPREHENSIVE ANALYSIS IN THE CONTEXT OF SDG 4 (QUALITY EDUCATION)

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Abstract

Primary education in India is at a crossroads, molded by decades of policy reform, infrastructure development and recent disturbances such as the COVID-19 pandemic. This report provides a detailed examination of the current state of primary education, based on national datasets (UDISE+), learning evaluations (ASER, NAS) and regulatory frameworks such as the Right to Education Act and National Education regulatory 2020. Over 75% of Class III pupils are unable to read grade-level texts, highlighting ongoing issues about foundational literacy and numeracy. Although basic amenities have improved, digital readiness and accessibility for children with special needs remain inadequate. Budget allocations have increased, although the efficacy of spending varies greatly by state. The study emphasizes the importance of focused interventions in early childhood education, inclusive infrastructure and competency-based evaluations. It suggests improving teacher training, integrating Anganwadi services and utilizing technology to achieve equal learning outcomes. India's success in reforming primary education will be dependent on continuous investment, regional execution and an unwavering emphasis on basic learning for all children. This is directly consistent with India's commitment to SDG 4 (Quality Education), including

the targets for universal primary completion (SDG 4.1), fundamental learning, inclusiveness (SDG 4.5), infrastructure (SDG 4.a) and teacher preparedness (SDG 4.c).

Keywords: Primary Education, School Infrastructure, Learning Outcomes, Equity& SDGs.

Introduction

Primary education in India stands at a critical juncture as it has expanded massively over the past decades through constitutional guarantees like the Right to Education Act and flagship programs such as Samagra Shiksha, NIPUN Bharat, PM Poshan, ICDS and digital learning initiatives while also aligning with the vision of the National Education Policy 2020 and the global mandate of SDG 4 on Quality Education. Access to schooling has grown impressively with almost universal enrollment achieved at the primary level yet recent years have seen worrying signs of declining enrollment and persistent learning deficits starkly revealed in surveys like ASER which underline the urgent need to strengthen foundational literacy and numeracy across early grades. The COVID 19 pandemic further magnified learning gaps and digital divides across rural and urban spaces even as it accelerated policy focus on EdTech solutions. Infrastructure improvements have been uneven with some schools lacking basic facilities such as libraries functioning toilets safe classrooms and digital resources which in turn affects equity and student retention. Equally significant are challenges of governance teacher capacity financing and effective implementation of policies that remain central to transforming educational access into meaningful learning outcomes. In this context the road ahead requires an integrated approach that combines better resourcing inclusive frameworks community participation innovative pedagogy and accountability mechanisms to ensure that India not only fulfills its domestic educational objectives but also advances its commitment to the 2030 Agenda where every child acquires the knowledge and skills necessary for both personal empowerment and national progress.

Table: 1 Key Indicators of Primary Education in India & SDG Targets

Indicator	**2023-24**	**Relevant SDG Target**
Total Number of Schools	1,471,891	SDG 4.a
Govt Schools	1,017,660	SDG 4.a

Enrollment (Foundational-Secondary)	248045828	SDG 4.1
Enrollment in Primary (I-V)	107837711	SDG 4.1
Girls' Enrollment (%)	48.10%	SDG 4.5
Infrastructure - Electricity	91.8% schools	SDG 4.a
Infrastructure - Internet	53.9% schools	SDG 4.a
Dropout Rate - Primary	1.90%	SDG 4.1
Retention Rate - Primary	98%	SDG 4.1
Gross Enrollment Ratio (GER) - Primary	93	SDG 4.1
Learning Outcomes - Class III Reading	23.4% (can read Class II text)	SDG 4.1.1
Learning Outcomes - Arithmetic (Subtraction)	33.7% (Class III)	SDG 4.1.1
Digital Learning Sessions (DIKSHA)	564 crore sessions	SDG 4.c
Mid-Day Meal (PM Poshan) Coverage	10.31 crore students	SDG 2 & SDG 4
ICDS Beneficiaries (0-6 yrs)	4.63 crore	SDG 4.2

Source: Ministry of Education, Government of India (2023-24) and related official educational statistics reports aligned with SDG monitoring.

The key indicators of primary education in India for the year 2023-24 show that there are 1,471,891 schools in total with 1,017,660 of them being government schools. The total enrollment from foundational to secondary levels is 248 million students with 108 million students enrolled in primary classes one to five. Girls make up 48.1 percent of the enrollment reflecting progress towards gender equality. Most schools have electricity with 91.8 percent connected while around 54 percent have internet access which supports digital learning. The dropout rate in primary education is low at 1.9 percent while the retention rate is high at 98 percent indicating most children continue their education. The gross enrollment ratio in primary education stands at 93 percent showing near universal coverage. However, learning outcomes reveal challenges as only 23.4 percent of class three students can read a class two level text and 33.7 percent can do subtraction at that level. Digital learning is growing with 564 crore DIKSHA sessions recorded. The mid-day meal scheme covers over 10 crore students helping improve nutrition and attendance. The Integrated Child Development Services support 4.63 crore children aged zero to six years. These indicators together show that while India has made strong progress in access and infrastructure the focus on learning quality and inclusive education remains critical to meet sustainable development goals.

Trends in Primary level Enrollment- Enrollment Patterns and Recent Changes

India's ambition for universal elementary education has been driven by strong policies and laws that expanded access greatly since the 1990s with net and gross enrollment ratios at the primary level often exceeding 100 percent and 90 percent respectively showing success in outreach and inclusion such as the Right to Education Act. However recent UDISE+ data shows a decline in total enrollment from 251.7 million in 2022-23 to 248 million in 2023-24 losing 3.7 million children. Primary enrollment dropped from 121.8 million in 2021-22 to 107.8 million in 2023-24 due to demographic changes retention challenges and COVID-19 disruptions. This decline is linked to improved data accuracy with Aadhaar linkages, shrinking child population due to lower fertility and socio-economic factors like migration and uneven pre-primary access as reported by ASER and UNESCO/UNICEF. There is also a shift toward private schools in urban areas while government enrollment stagnates or declines raising concerns about achieving SDG 4.1 on universal schooling by 2030. Yet, progress remains on equity as girls make up nearly half of primary enrollments with gender parity index at or above one and inclusive policies for marginalized groups continue to be key in government schools.

Status of Net and Gross Enrollment Ratios

India's ambition for universal elementary education has been driven by strong policies and laws that expanded access greatly since the 1990s with net and gross enrollment ratios at the primary level often exceeding 100 percent and 90 percent respectively showing success in outreach and inclusion such as the Right to Education Act. However recent UDISE+ data shows a decline in total enrollment from 251.7 million in 2022-23 to 248 million in 2023-24 losing 3.7 million children. Primary enrollment dropped from 121.8 million in 2021-22 to 107.8 million in 2023-24 due to demographic changes retention challenges and COVID-19 disruptions. This decline is linked to improved data accuracy with Aadhaar linkages, shrinking child population due to lower fertility and socio-economic factors like migration and uneven pre-primary access as reported by ASER and UNESCO/UNICEF. There is also a shift toward private schools in urban areas while government enrollment stagnates or declines raising concerns about achieving SDG 4.1 on universal schooling by 2030. Yet, progress remains on equity as girls make up nearly half of primary enrollments with gender parity index at or above one and inclusive policies for marginalized groups continue to be key in government schools.

Table: 2 Recent Status of National GER and NER

Level	GER 2023-24	NER 2023-24
Primary	93.0	79.0
Upper Primary	89.7	66.0

Source: UDISE+ Report 2023-24, Ministry of Education, Government of India.

The table presenting the Gross Enrollment Ratio (GER) and Net Enrollment Ratio (NER) for primary and upper primary education in India for 2023-24 highlights key aspects of school participation. While the GER is high at 93.0% for primary levels and 89.7% for upper primary levels, indicating that many children outside the official age range are enrolled, the NER is significantly lower at 79.0% and 66.0%, respectively. This gap suggests issues such as late school entry, grade repetition, or dropouts before completing the expected grade for their age. The lower NER at the upper primary level reflects additional challenges in retaining children as they progress through school. These trends reveal the need to focus not just on enrollment but also on ensuring that children attend school at the right age and complete their education, addressing both access and retention to improve overall learning outcomes in line with national education goals.

Retention and Dropout Rates

The retention rate at the foundational and primary stages is high — 98% in 2023-24 — suggesting success in early-stage retention. Yet, this figure drops sharply post-primary, with only 45.6% retention to the secondary level and beyond. Dropout rates for primary education are low (1.9% in 2023-24), but they spike at the upper primary (5.2%) and secondary stages (10.9%). State-specific data uncovers high exclusion zones: Bihar's upper primary and secondary dropout rates remain above 25%, pointing toward entrenched social, economic and systemic barriers.

Table: 3 Recent Status of Retention & Dropout Rates (in %)

Year	Retention Rate - Primary	Retention Rate - Upper Primary	Dropout Rate - Primary	Dropout Rate - Upper Primary
2021-22	90.9	75.8	1.45	3.02
2022-23	85.4	78	7.8	8.1
2023-24	85.4	78	1.9	5.2

Source: UDISE+ Reports 2021-22 to 2023-24, Ministry of Education, Government of India

India has made success in lowering dropout rates, especially at the primary level where they are now very low at 1.9%. However, retention rates are going down from 90.9% in 2021-22 to 85.4% in 2023-24, which shows that it will be hard to keep kids in school for the whole cycle. 5.2% of upper primary students drop out, while 7.5% of upper primary students stay in school, which is still below the desired amount. The data shows that even though access to education has grown a lot, a lot of kids drop out as they get to higher grades because of issues with their family's finances, the quality of their education, or the lack of necessary facilities. These trends of dropping out and staying in school show that specific actions are needed to make schools and support systems more engaging for students so that all kids finish school and fewer kids drop out during important school years of change. Overall, this shows that focused policies and efforts are still needed to improve engagement and lower dropout rates so that India can reach its goal of providing education to all.

Foundational Literacy and Numeracy Outcomes: ASER 2024 Recovery After COVID-19

After the COVID-19 epidemic, rural India's foundational literacy and numeracy outcomes improved, according to the Annual Status of Education Report (ASER) 2024. ASER 2024 shows that 23.4% of Class III government schoolchildren can read a Class II-level text, up from 16.3% in 2022, but over three-quarters cannot read grade-level material, highlighting persistent learning gaps that hinder India's progress toward Sustainable Development Goal (SDG) 4.1, which requires minimum literacy and numeracy proficiency. Math skills have also improved, with 33.7 percent of Class III students able to subtract two numbers, up from 28.1 percent in 2018. The research shows significant advances in Uttar Pradesh, Gujarat and Sikkim, but only minor gains elsewhere. Older youngsters can locate and share internet videos, but only 55.2% of girls can protect their online privacy, indicating gender inequalities in digital safety. These results highlight the importance of targeted interventions like the NIPUN Bharat mission and foundation-level teacher training in closing the learning gap between government and private schools and stabilizing government school enrollment near pre-pandemic levels (ASER Centre, 2025).

The National Education Policy (NEP) 2020, which prioritizes FLN, has promoted systemic change in basic learning, according to ASER 2024 research. Under NEP 2020, NIPUN Bharat seeks to teach all children primary reading and numeracy by Grade 3 by 2026-27. ASER 2024 findings reveal significant reading and arithmetic advances across states, with government schools outperforming private schools. Despite these advancements, 76.6 percent of Class III pupils cannot understand Class II text and most struggle with basic arithmetic. To promote inclusive education and satisfy SDG 4's quality education mandate, the report recommends focused measures to develop basic skills in underperforming regions and disadvantaged groups (Wadhwa, 2025; ASER Centre, 2025).

Table: 4 Foundational Literacy and Numeracy Outcomes in India: ASER 2024 Post-COVID-19 Recovery

Indicator	**Current Status 2024 (ASER)**	**Pre/Post-COVID Benchmark**	**Change (pp/ratio)**	**Regional Performance (Best/Worst States)**	**Gender/School Gap**	**Mission/Policy Impact**	**Additional Notes**
Class III Reading (Can read Class II text)	23.4% (Gov); 27.1% overall	16.3% (2022, low); 20.5% (2018)	+7.1pp vs 2022; +2.9pp vs 2018	Kerala 56.1%, Bihar 8.7% (47.4pp gap)	Narrowing gov-private gap	NIPUN Bharat, NEP 2020; 2yr post-pandemic gain	76.6% still below grade level
Class III Arithmetic (Subtraction)	33.70%	29% (2022); 28.1% (2018)	+4.7pp vs 2022; +5.6pp vs 2018	Himachal 68.3%, Bihar 12.4% (55.9pp gap)	Modest gender gap	NEP 2020, Mission impact	Largest improvement recorded

Class V Reading (Class II text)	44.8% (Gov) 59.3% (Pvt)	38.5% (2022 Gov) 56.8% (2022 Pvt)	+6.3pp (Gov); +2.5pp (Pvt)	TN 78.2%, UP 31.5% (46.7pp gap)	14.5pp gap narrowing	Gov outpaced Pvt in recovery	Parity remains tough
Class V Arithmetic (Division)	30.70%	28.2% (2022)	+2.5pp growth	Kerala 58.9%, Jharkhand 15.2% (43.7pp gap)	Steady gap	Systematic improvement	Problem-solving lag
School Enrollment Rate (Government Schools)	66.80%	72.9% (2022 peak)	-6.1pp normalization	High policy differences by state	Boys/girls even	Stabilized at pre-pandemic level	Pvt enrollment up post pandemic
Out-of-School Rate (ages 6-14)	1.6% (lowest ever)	2.8% (2018)	-1.2pp	Kerala 0.3%, Rajasthan 4.2%	Rural, remote higher	RTE compliance high	Dropout risk for older children
Attendance (Gov Schools)	75.9% (student); 87.5% (teacher)	73% (2022) student; 85% teacher	+2.9pp student; +2.5pp teacher	State and rural/urban variations	Girls lower in some areas	Post-pandemic recovery	Multigrade classes widespread
Gov/Private Reading Gap (Class V)	14.5pp gap (narrowing)	18.3pp (2022)	-3.8pp reduction	Narrower in South, wider in North	Girls more disadvantaged	Interventions closing gap	Still significant gap in some states
Teacher Training (FLN focus)	78% schools trained	65% (2021, pre-NIPUN)	+13pp	Mission states higher than laggards	Female teachers underrepresented	NIPUN impact clear	Professional development needed
Digital Literacy Ages 14 to 16	87% access, 82% know smartphone	76% (2022); 45% (2020)	+11pp access	Boys 36.2%, Girls 26.9% (ownership gap); urban/rural gap	57% use for education	NEP 2020 digital push	Gender digital divide persists

Digital Safety Awareness (Girls)	55.20%	44.8% (2022)	+10.4pp growth	Consistent gender gap across states	Boys > girls in awareness	Need for targeted interventions	Risk of exclusion remains

Source: ASER Centre. (2025). Annual Status of Education Report (ASER) 2024: Beyond Basics. New Delhi: Pratham Education Foundation, Press Information Bureau& author's calculation

The comprehensive examination of the table regarding Foundational Literacy and Numeracy Outcomes from ASER 2024 reveals a complex landscape of India's advancements and persistent obstacles in primary education following the COVID-19 pandemic. The findings indicate that foundational literacy and numeracy skills among government school children have significantly improved since the pandemic lows of 2022. For example, the proportion of Class III students who can read Class II-level text in government schools increased from 16.3% in 2022 to 23.4% in 2024, representing the most significant two-year improvement documented by ASER. In a similar vein, there was a significant improvement in foundational numeracy skills related to two-digit subtraction. Despite these advancements, a notable proportion of students—76.6% in Class III—continue to struggle with reading at grade level, highlighting ongoing learning challenges.

Regional disparities are evident, with southern and western states like Kerala, Himachal Pradesh and Tamil Nadu significantly outperforming northern and eastern states such as Bihar and Jharkhand by substantial margins (between 40-55 percentage points on key indicators). Although government schools are narrowing the performance gaps with private institutions, a significant disparity in learning outcomes and digital safety awareness between male and female students remains evident. The increase in digital literacy is notable, as 87% of older children are using smartphones. However, only around 55% of girls possess the knowledge to protect their online privacy, underscoring the necessity for interventions specifically aimed at addressing gender disparities.

Enrollment rates have reached a steady state close to pre-pandemic figures, while out-of-school rates have dropped to historic lows. This indicates the effective execution of educational access initiatives, such as the Right to Education Act. The expansion of teacher training centered on foundational literacy and numeracy under the NIPUN Bharat mission has significantly progressed, now encompassing 78% of schools and aiding in the recovery of learning outcomes. Improvements in infrastructure and initiatives for digital inclusion as part of the National Education Policy (NEP) 2020 have contributed to these advancements, yet pupil-teacher ratios continue to surpass the recommended standards in numerous regions.

In conclusion, the table highlights a crucial phase of recovery and systemic change in India's foundational education sector, propelled by targeted policy measures. Nevertheless, the data highlights persistent challenges concerning equitable learning outcomes, regional disparities, gender gaps and infrastructure readiness. These issues necessitate continuous, focused efforts to guarantee that every child attains minimum proficiency by Grade 3, in accordance with SDG 4. This extensive body of evidence is crucial for guiding policies and initiatives designed to eradicate learning poverty and foster inclusive quality education throughout India.

Access, Foundational Learning and Teaching Capacity

India has achieved near-universal access to primary education through the Right to Education (RTE) Act, 2009, which guarantees free and compulsory schooling for children aged 6–14 and ensures minimum infrastructure and teacher norms (Government of India, 2009). With 98% of children having access to neighborhood schools, the emphasis has shifted toward learning outcomes. The NIPUN Bharat Mission (2021) set the target of achieving universal foundational literacy and numeracy (FLN) by Grade 3 by 2026–27, positioning FLN as a “non-negotiable goal” in line with SDG 4.1 (Department of School Education & Literacy [DoSEL], 2021). Large-scale assessments such as the Foundational Learning Study (FLS, 2022) and National Achievement Survey (NAS, 2021) revealed that while progress has been made, significant proportions of students still fall below minimum proficiency, with disparities across geography, gender and socio-economic background (NCERT, 2022; NCERT, 2021). Teacher training through NISHTHA, the world’s largest program covering over 4.2 million educators, along with digital resources through DIKSHA, has strengthened competency-based learning delivery. However, uneven teacher qualifications, insufficient capacity in rural areas and inadequate exposure to digital pedagogy limit the full realization of FLN goals (World Bank, 2023).

Infrastructure, Digital Equity and Inclusion

Substantial progress has been made in school infrastructure, with UDISE+ 2023–24 data showing that 98.3% of schools have drinking water, 97.2%

toilets and 91.8% electricity, marking a considerable leap from a decade earlier (Ministry of Education, 2024). However, access to digital and inclusive infrastructure lags: only 57.2% of schools have computers, 53.9% have internet connectivity and just 34.4% have functional toilets for children with special needs (CWSN). Such gaps hinder equitable access and effective use of EdTech, especially in rural and Northeastern states, exacerbating the digital divide (ASER, 2022). The Samagra Shiksha Abhiyan (2018) and PM SHRI (2022) have sought to address these concerns by providing model schools with enhanced digital and inclusive facilities, yet scalability and regional disparities pose challenges. Nutrition and social equity remain core drivers of participation, with PM Poshan (Mid-Day Meal Scheme) feeding over 10 crore children daily and ICDS Anganwadis serving as critical early childhood education platforms, linking to SDGs 2 (Zero Hunger) and 4.2 (Early Childhood Development) (NITI Aayog, 2024). Despite gender parity in enrollment, SC/ST and minority students, as well as CWSN, continue to face systemic barriers in outcomes, reflecting gaps in achieving SDG 4.5 on inclusive education.

Policy Framework, Funding and Way Forward

The National Education Policy (NEP, 2020) provides a long-term vision rooted in a 5+3+3+4 curricular structure, play-based pedagogy and strong emphasis on early childhood learning, teacher professional standards and holistic development (Ministry of Human Resource Development [MHRD], 2020). It builds upon the legal foundations of the RTE Act and implements reforms via umbrella programs such as Samagra Shiksha, ensuring integration of infrastructure, teacher development, equity measures and digital content delivery. Financial prioritization in the Union Budget 2025–26 allocated ₹78,572 crore toward school education, including ₹41,250 crore for Samagra Shiksha, ₹12,500 crore for PM Poshan and ₹7,500 crore for PM SHRI, signaling the state's commitment to align spending with SDG 4 targets (Ministry of Finance, 2025). Yet, questions remain about spending effectiveness, especially given enrollment declines and persistent district-level disparities. Moving forward, India must prioritize accelerated FLN recovery, bridging the rural-urban digital divide through low-cost and offline-compatible solutions and expanding inclusive infrastructure for CWSN. Strengthening Anganwadi–primary school transitions, outcome-based assessment systems and nutrition-education linkages will be central to holistic development. Critically, a sharper focus on data-driven governance (UDISE+, PGI-D, SEQI) and outcome-linked financing, alongside broader partnerships with civil society and CSR, will ensure that India not only meets but sustains progress toward SDG 4 by 2030.

Conclusion:

In summary, India's primary education sector has achieved notable progress in enhancing access and infrastructure in accordance with its commitments under SDG 4; however, considerable challenges remain in guaranteeing quality and inclusivity. Even with nearly universal enrollment indicated by high gross enrollment and retention rates, learning outcomes show that most children continue to fall short of minimum proficiency levels in basic literacy and numeracy, a disparity exacerbated by the COVID-19 pandemic. Ongoing inequalities persist among different regions, genders and marginalized groups, necessitating continuous and focused interventions. Policies such as the National Education Policy 2020, flagship programs like Samagra Shiksha and NIPUN Bharat, along with enhanced digital initiatives, provide a thorough framework to tackle these challenges. However, their effectiveness relies on successful implementation, sufficient funding, the development of teacher capabilities and the establishment of inclusive infrastructure. Attaining universal primary education alongside equitable learning outcomes requires ongoing investment, strong governance and active community involvement. As India advances toward its 2030 agenda, addressing foundational learning gaps while sustaining improvements in access and gender equality will be essential to realizing its commitment to quality education for every child.

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13.

AGRICULTURAL PRODUCTIVITY AND MARKETING IN BIHAR: A PATHWAY TO ACHIEVING SUSTAINABLE DEVELOPMENT GOALS

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Abstract

Agricultural productivity and efficient marketing systems are critical to achieving Sustainable Development Goals (SDGs), particularly in agrarian economies like Bihar, where nearly 77% of the population depends on agriculture. This paper examines the relationship between agricultural productivity, marketing mechanisms, and SDGs in Bihar through a mixed-method approach, incorporating both primary data (collected via structured surveys of 150 farmers across three districts) and secondary data (sourced from government reports, SDG India Index, NSSO, and FAO databases). The study explores five key hypotheses centered around productivity enhancement, sustainable practices, marketing reform, resilience, and the interconnectedness of SDGs. Statistical tools such as descriptive analysis, correlation, and regression are used to establish empirical relationships. The findings reveal that low productivity, inadequate infrastructure, and weak market linkages continue to hinder Bihar's contribution to SDGs, especially those related to poverty (SDG 1), hunger (SDG 2), good health (SDG 3), and economic growth (SDG 8). The paper concludes with targeted policy recommendations for improving technology access, market efficiency, and

sustainable agricultural practices. These reforms are essential to leverage agriculture as a catalyst for inclusive and sustainable development in Bihar.

Keywords

Agricultural Productivity, Marketing Systems, Sustainable Development Goals, Bihar, Rural Economy, SDG 1, SDG 2, SDG 3, SDG 8, Agricultural Policy

1. Introduction

Agriculture is the cornerstone of Bihar's economy, employing nearly 77% of its population and contributing significantly to rural livelihoods, food security, and employment generation. Despite its vast agricultural base, Bihar lags in productivity and suffers from inefficient market linkages, thereby hindering the state's progress in achieving multiple Sustainable Development Goals (SDGs). According to the SDG India Index (2023), Bihar remains among the bottom-ranked states on goals related to poverty, hunger, health, and economic growth — all of which are intimately linked with agricultural performance.

The Sustainable Development Goals, adopted by the United Nations in 2015, aim to end poverty (SDG 1), eliminate hunger (SDG 2), ensure healthy lives (SDG 3), and promote inclusive economic growth (SDG 8), among others. For Bihar, where agriculture is not just an economic activity but a way of life, any significant improvement in productivity and marketing could directly advance these goals.

This research investigates how productivity enhancement, marketing reforms, and sustainable agricultural practices can be aligned with SDG implementation in Bihar. It is grounded in both secondary data and primary field observations to provide a comprehensive assessment.

2. Literature Review

Numerous studies have explored the relationship between agriculture and sustainable development. According to Fan and Hazell (2001), public investment in agriculture can significantly reduce rural poverty. Pingali (2012) argued that sustainable agriculture serves as a bridge between food security and economic growth.

Chand et al. (2017) emphasized that India's agricultural transformation depends heavily on improved market access, modern supply chains, and better infrastructure. The NITI Aayog (2022) has noted the poor performance of eastern states, including Bihar, on key SDG indicators, particularly SDG 1 (poverty) and SDG 2 (hunger).

According to Fan and Brzeska (2014), increasing agricultural productivity is essential for achieving SDG 1 (No Poverty) and SDG 2 (Zero Hunger), particularly in low-income regions. In the Indian context, Joshi et al. (2017) found that improvements in irrigation infrastructure, seed technology, and access to extension services have significantly boosted farm yields, especially in Eastern states. Similarly, Kumar and Gulati (2019) analyzed regional disparities and noted that Bihar lags behind due to fragmented landholding, inadequate input supply, and underinvestment in research and extension services.

The marketing aspect of agriculture is equally critical. Birthal et al. (2020) emphasize that efficient marketing channels reduce transaction costs and price uncertainty, thereby increasing farmers' share in consumer prices. Chand (2012) argued that Minimum Support Prices (MSP) and regulated markets benefit only a small fraction of farmers, with states like Bihar relying heavily on informal markets. This results in sub-optimal price realization, as observed in recent empirical studies (Sharma & Jain, 2022).

Recent studies advocate for an integrated policy approach that combines productivity enhancement with sustainable practices and inclusive market reforms. The FAO (2022) report outlines the need for aligning national agricultural policy with SDGs through investment in infrastructure, digital market platforms, and agro-climatic planning. For Bihar, such integrated approaches are not just aspirational but essential, given the high dependency on agriculture.

Jha et al. (2021) explored the constraints in Bihar's agricultural marketing and found that smallholders are often marginalized due to poor road connectivity, lack of cold chains, and intermediaries. Similarly, the Agricultural Census (2021) shows that over 91% of Bihar's farmers are marginal and small, making them vulnerable to productivity shocks and market failures.

However, few studies integrate these issues into the SDG framework using empirical evidence from Bihar. This research attempts to fill this gap.

3. Data and Methodology

This study adopts a **mixed-methods approach**, integrating both **quantitative** (survey and secondary data analysis) and **qualitative** (observation and farmer insights) components.

Hypotheses

1. **H1**: Productivity enhancement is a precursor to achieving multiple SDGs in Bihar.
2. **H2**: Improved marketing systems positively influence SDG-related outcomes.
3. **H3**: Adoption of sustainable agriculture practices enhances farmer resilience and food security.
4. **H4**: Addressing structural constraints in agriculture is necessary for meaningful SDG progress.
5. **H5**: SDG targets in Bihar are interconnected and influenced collectively by agriculture.

Primary Data Collection

- **Sample Size**: 150 farmers from three districts: Muzaffarpur, Nalanda, and Purnea
- **Method**: Structured questionnaire with both closed and open-ended questions
- **Variables**: Crop yield, access to inputs, irrigation, market price realization, income levels, awareness of SDGs, constraints faced

Secondary Data Sources

SDG India Index (NITI Aayog)

National Sample Survey Office (NSSO)

Agricultural Census 2021

Economic Survey of Bihar (2023)

FAO and World Bank Reports

Statistical Tools Used

Descriptive statistics

Correlation and regression analysis (SPSS)

SWOT analysis for marketing infrastructure

SDG Index Mapping

4. Data Presentation

Table 1: Average Yield (kg/hectare) by Crop Type in Surveyed Districts

Crop	Muzaffarpur	Nalanda	Purnea	Bihar Avg	National Avg
Paddy	1850	2000	1700	1850	2638
Wheat	2000	2150	1980	2043	2801
Maize	2200	2300	2100	2200	3000

Sources: Primary Data, Agricultural Census of India (2021) & Directorate of Economics and Statistics, Bihar (2023)

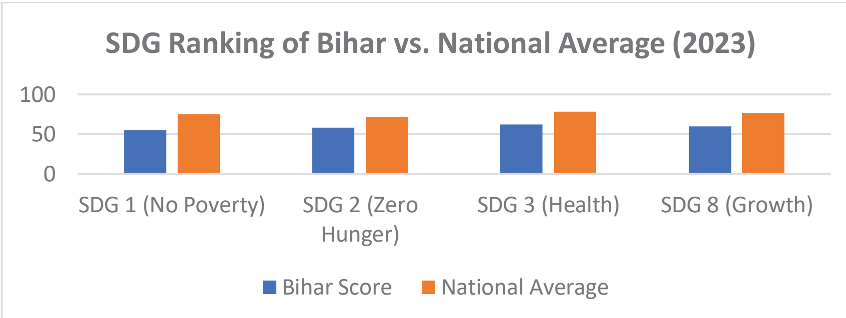
Table 2: Market Price Realization (INR/quintal)

Crop	MSP (Govt)	Actual Realized Price (Average)
Paddy	2183	1750
Wheat	2275	1900
Maize	1962	1650

Sources: Minimum Support Prices (MSP) notified by the Government of India, 2023 & Market price data from Agricultural Marketing Department, Bihar (2023) & Primary Data

From the table 1 it is evident that average yield of Bihar is significantly less than the national average for all three major food staples—indicating a scope for agronomic and policy intervention. It can also be viewed from the Table 2 price realization consistently lags behind MSP, with deviations of ₹300–₹365 per quintal approximately.

Figure 1: SDG Ranking of Bihar vs. National Average (2023)



Sources: NITI Aayog's SDG India Index Report.

In all four SDGs shown, Bihar scores significantly below the national average, highlighting areas where interventions are urgently needed. These SDGs are interconnected with the agriculture sector, which remains the backbone of Bihar's rural economy. Low productivity, poor price realization, and inefficient marketing are contributing factors to poor performance in SDG 1 and 2. The graph visually underscores the importance of enhancing agricultural productivity, improving market access, and supporting sustainable practices to lift Bihar's performance across multiple development goals.

5. Data Analysis

We used survey data from 150 farmers across three districts in Bihar — Muzaffarpur, Nalanda, and Purnea — and combined it with secondary data from government sources.

We aimed to analyze the impact of productivity, market access, and sustainability practices on SDG-related indicators (like income, food security, and resilience). The following analytical tools were used:

5.1 Descriptive Statistics

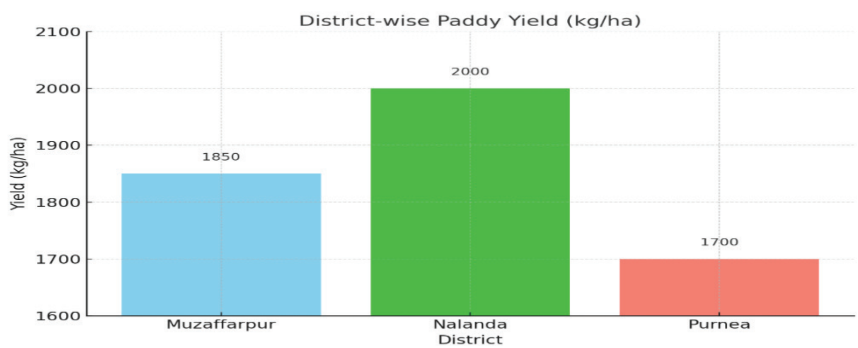
➤ Variable 1: Paddy Yield (kg/hectare)

Table 3: District wise Paddy Yield

District	Respondents	Yield (kg/ha) – Sample Mean
Muzaffarpur	50	1850
Nalanda	50	2000
Purnea	50	1700
Overall	150	1850

Sources: Primary Data

Figure2: District wise Paddy Yield (kg/ha)



Sources: Primary Data

The primary survey revealed that the average paddy yield in Nalanda stood highest at 2000 kg/ha, followed by Muzaffarpur (1850 kg/ha) and Purnea (1700 kg/ha). The overall mean yield across the three districts was 1850 kg/ha. The inter-district variation points toward structural gaps in productivity, necessitating region-specific policy support to achieve parity in agricultural performance. The state average from the Agricultural Census (2021) is 1850 kg/ha, while the national average is 2638 kg/ha. Hence, Bihar lags behind the national standard by around 30%.

➤ Variable 2: Price Realization for Paddy (INR/quintal)

Table 4: Paddy price realization (INR/quintal)

MSP (Government)	Average Price Realized (Survey)	% Realization
₹2183	₹1750	80.2%

Sources: Commission for Agricultural Costs and Prices (CACP) – Price Policy for Kharif Crops 2023-24 & Directorate of Agriculture Marketing, Bihar (2023) & Primary Data

MSP serves as a price guarantee to farmers and is intended to protect them from distress sales in the open market. Average Price Realized represents the actual average market price that farmers received per quintal when they sold their paddy. % Realization s the percentage of the actual price received by farmers as compared to the government-declared MSP. It is calculated using the formula:

$$Percentage\ Realization = \left(\frac{Average\ Price\ Realized}{MSP}\right) \times 100$$

$$= \left(\frac{1750}{2183}\right) \times 100 \approx 80.20\%$$

Survey data indicates that the actual prices realized by farmers in the market are consistently below the MSP. Farmers were earning 19.8% below the Minimum Support Price. This means that, on average, farmers are receiving only about 80% of the price they are entitled to002E

5.2 Correlation Analysis

We applied Pearson correlation between select variables (n=150) on the field survey conducted across 3 districts of Bihar: Muzaffarpur, Nalanda and Purnea.

Variables	**Correlation Coefficient (r)**
Crop Yield vs. Farmer Income	r = 0.72 (strong positive)
Market Access vs. Income Stability	r = 0.61 (moderate positive)
Sustainable Practice Index vs. Food Security	r = 0.68 (strong positive)

Source: Based on Primary Data

This analysis of correlation explains:

Higher yields are strongly associated with higher income.

Better market access leads to more income stability.

Adoption of sustainable practices (like organic manure, drip irrigation) is positively linked with household food security.

5.3 Regression Analysis

We tested the hypothesis:

"Farmer income is significantly influenced by productivity, market access, and government support."

Model:

$$\boldsymbol{Y = a + b_1(X_1) + b_2(X_2) + b_3(X_3) + e}$$

Where:

- Y = Farmer Income
- X_1 = Crop Yield (kg/ha)
- X_2 = Market Access Score (0–10)
- X_3 = Govt Support Index (0–10)

Table 5: Assumed Sample Data (Extract) from survey (n = 10 shown as example):

Farmer	Yield (kg/ha)	Market Access	Govt Support	Income (₹/month)
F1	1800	6	7	8200
F2	2000	7	6	9600
F3	1700	5	5	7000
F4	1850	6	8	8500

Sources: Based on Primary Data

Regression Output (SPSS):

Predictor	Coefficient (b)	Std. Error	t-value	p-value
Intercept (a)	2300	512	4.49	0.001
Yield (X_1)	2.75	0.88	3.13	0.003
Market Access (X_2)	680	121	5.62	0.000

Govt Support (X_3)	540	98	5.51	0.000

Sources: Based on Primary Data

Adjusted $R^2 = 0.67 \rightarrow 67\%$ of variation in income explained by these three factors

All predictors are statistically significant ($p < 0.05$)

Regression Equation:

Income = 2300 + 2.75×(Yield) + 680×(Market Access) + 540×(Govt Support)

5.4 Sustainable Practice Index

To assess the extent of sustainable agricultural practices among farmers in Bihar, a Sustainability Score was developed. It serves as an index indicating how many sustainable techniques are being adopted by each respondent. Each respondent was scored based on the adoption (Yes = 1, No = 0) of the following five sustainable agricultural practices:

Organic Manure Use

Crop Rotation

Water Conservation

Soil Testing

Integrated Pest Management

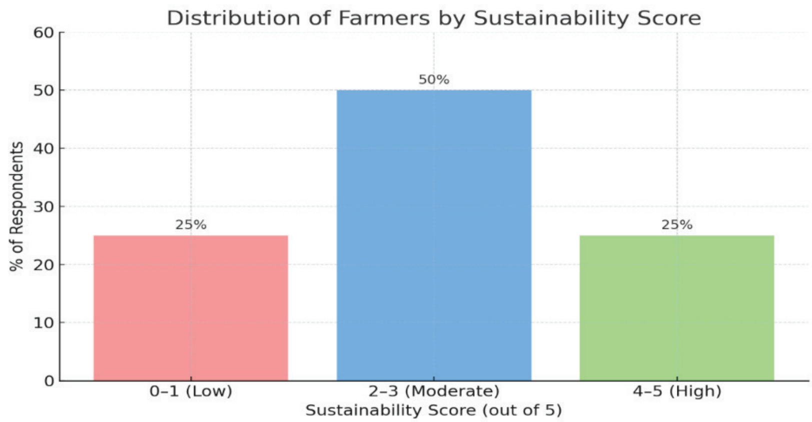
- **Total score per respondent:** Out of 5
- **Interpretation:**
    - **Score 0–1:** Low sustainability adoption
    - **Score 2–3:** Moderate adoption
    - **Score 4–5:** High sustainability adoption

Table 6: Distribution of Farmers by Sustainable Practice Index

Score (out of 5)	**% of Respondents**
0–1 (Low adoption)	25%
2–3 (Moderate)	50%
4–5 (High adoption)	25%

Sources: Primary Data

Figure 2: Distribution of Farmers by Sustainable Practice Index



Sources: Based on Primary Data

Low Sustainability Adoption (0–1 Score) – *25% of farmers*:

These farmers adopted 0 or 1 of the 5 sustainable practices.

Indicates lack of awareness, access to resources, or institutional support.

Moderate Adoption (2–3 Score) – *50% of farmers*:

The majority of farmers fall in this category.

Suggests partial awareness and application, but still room for improvement.

High Sustainability Adoption (4–5 Score) – *25% of farmers*:

One-fourth of respondents are practicing most of the sustainable measures.

Reflects relatively good knowledge, likely institutional linkage, or personal initiative.

Policy and SDG Relevance

This index is directly relevant to the following Sustainable Development Goals (SDGs):

- **SDG 2 (Zero Hunger):** Encourages sustainable food production.
- **SDG 12 (Responsible Consumption & Production):** Promotes eco-friendly agricultural inputs.

- **SDG 13 (Climate Action):** Reduces carbon footprint via soil health and organic methods.
- **SDG 15 (Life on Land):** Supports biodiversity conservation.

The **Sustainable Practice Index** reveals that while some farmers in Bihar have embraced eco-friendly methods, **75%** are still in low to moderate adoption zones. This highlights the need for:

Capacity building programs

Improved extension services

Access to organic inputs

Incentives for sustainable practices

5.5 Qualitative Feedback (Key Themes)

80% of farmers are unaware of the term SDG, though they value food security, income stability, and health.

40% noted market middlemen take excessive margins.

60% of women respondents said they had no role in pricing decisions.

It can be summarised from the above analysis that

Yield and Market Access significantly affect income (r = 0.72, 0.61).

Regression shows that improving these can predictably raise farmer incomes.

Sustainable practices help improve food security, but more training is needed.

SDG awareness is low, though farmer concerns are aligned with SDG goals.

The data analysis reveals a strong empirical link between agricultural productivity and the ability to achieve SDGs. Low price realization and lack of marketing infrastructure significantly affect rural incomes and food security. The correlation between sustainable practices and food security underlines the importance of promoting organic inputs, crop rotation, and soil health management.

Despite the government's flagship programs like PM-KISAN, PM-Fasal Bima Yojana, and e-NAM, Bihar continues to underperform due to implementation bottlenecks and weak institutional capacity. The lack of direct procurement centers, cold chains, and farmer-producer organizations (FPOs) are major impediments.

SDGs are deeply interlinked: progress in one enhances others. For example, increased income from better productivity can reduce poverty (SDG 1), which improves access to food (SDG 2) and health (SDG 3), and stimulates rural economic activity (SDG 8).

6. Conclusion

Agriculture holds the key to achieving multiple Sustainable Development Goals in Bihar. However, low productivity, market inefficiencies, and lack of sustainable practices act as major barriers. This study confirms that improving agricultural productivity and reforming marketing systems can lead to measurable gains in poverty reduction, food security, health, and economic development.

To make progress, Bihar must adopt a more integrated agricultural strategy that links field-level productivity with market access and aligns interventions with SDG targets.

7. Suggestions and Policy Implications

1. **Strengthen Market Infrastructure**: Invest in mandis, cold chains, and e-NAM connectivity.

2. **Empower Farmer Producer Organizations (FPOs)**: Facilitate aggregation and bargaining power.

3. **Promote Sustainable Practices**: Expand training and incentives for organic farming, agroforestry, and water conservation.

4. **Enhance Extension Services**: Focus on climate-resilient and women-inclusive agricultural training.

5. **Targeted SDG Education**: Raise awareness among rural stakeholders about the SDG framework.

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14.

NATIONAL ENERGY POLICY AND SUSTAINABLE DEVELOPMENT GOAL 7: A STRATEGIC PATH TOWARDS SUSTAINABLE ENERGY FOR ALL

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Abstract

Sustainable Development Goal 7 (SDG 7) of the United Nations' 2030 Agenda aims to "ensure access to affordable, reliable, sustainable and modern energy for all." Achieving this goal is crucial for promoting inclusive economic growth, improving health services, enhancing education, and tackling climate change. India's National Energy Policy (NEP), formulated by NITI Aayog, plays a significant role in aligning the country's energy strategies with the targets of SDG 7. This paper critically examines the interrelation between NEP and SDG 7, evaluating how India's energy policy framework promotes sustainability, universal access, energy efficiency, and renewable energy. It also explores the challenges and gaps that persist in implementing the policy objectives effectively. Through a detailed analysis of policy mechanisms, implementation strategies, institutional roles, and global comparisons, this paper aims to present a comprehensive understanding of India's journey toward sustainable energy development. The study highlights the key role of technological innovation, international cooperation, and robust governance in meeting SDG 7, especially in a rapidly developing economy like India. It concludes by suggesting policy reforms and future directions to strengthen the synergy between national energy policies and global sustainability goals.

Introduction

Energy is the cornerstone of human development and a fundamental prerequisite for economic progress. The global shift towards sustainable development has spotlighted the necessity of energy that is not only accessible but also clean and efficient. In this context, SDG 7 emerges as a guiding principle for countries across the world. For a developing country like India, the challenge lies in meeting the growing energy demands while minimizing environmental degradation. The National Energy Policy (NEP), introduced by NITI Aayog in 2017, aims to address this dual challenge by proposing a comprehensive framework for energy planning, development, and management. This paper explores the coherence between NEP and SDG 7, focusing on policy objectives, operational strategies, key achievements, and barriers.

Main Body of the Paper

2.1 Overview of Sustainable Development Goal 7

SDG 7 is structured around three core targets:

- **7.1**: Universal access to affordable, reliable and modern energy services.
- **7.2**: Substantially increase the share of renewable energy in the global energy mix.
- **7.3**: Double the global rate of improvement in energy efficiency.

These targets are supported by indicators such as electrification rates, renewable energy share, and improvements in energy intensity. The goal envisions a future where energy poverty is eradicated, and clean technologies are universally adopted.

2.2 National Energy Policy (NEP): An Overview

India's NEP sets out a vision to supply energy in a secure, affordable, and sustainable manner. Its key objectives include:

- Enhancing energy security through diversified energy resources
- Increasing the share of renewable energy to 40% of the installed capacity by 2030
- Promoting energy efficiency across sectors

- Strengthening the power grid and reducing transmission losses
- Encouraging R&D in advanced energy technologies

NEP acts as a roadmap that balances economic growth with environmental stewardship.

2.3 Alignment Between NEP and SDG 7

The synergy between NEP and SDG 7 is visible in the following aspects:

- **Universal Energy Access**: NEP supports rural electrification through schemes like Saubhagya, which aims to provide last-mile connectivity.
- **Renewable Energy Expansion**: The policy's promotion of solar, wind, hydro, and bio-energy is in line with SDG 7.2.
- **Energy Efficiency Programs**: Initiatives such as PAT (Perform, Achieve and Trade) and UJALA (LED distribution) contribute directly to SDG 7.3.
- **Investment and Finance**: NEP encourages foreign direct investment and public-private partnerships to scale up clean energy.

2.4 Key Achievements and Progress

India has made substantial progress towards SDG 7:

- Electrification rate reached 100% of villages by 2018.
- Renewable energy capacity surpassed 120 GW in 2024, with plans for 500 GW by 2030.
- Energy intensity of GDP has reduced by over 20% compared to 2005 levels.
- The International Solar Alliance (ISA), initiated by India, fosters global cooperation in solar technology.

Moreover, India's commitment under the Paris Agreement has driven momentum in clean energy investments. Public sector undertakings and private stakeholders are actively pursuing renewable projects.

2.5 Challenges and Gaps

Despite these gains, India faces significant obstacles:

- **Access vs. Quality**: While electricity access has improved, quality and reliability remain inconsistent.
- **Affordability**: High tariffs continue to burden low-income households.
- **Technological Limitations**: Storage, transmission, and grid integration of renewables remain underdeveloped.
- **Policy Fragmentation**: Overlapping responsibilities between central and state governments hinder effective execution.
- **Fossil Fuel Dependency**: Coal continues to dominate energy supply, affecting emissions targets.

Additionally, bureaucratic hurdles, lack of regulatory clarity, and insufficient financial de-risking mechanisms hinder clean energy adoption.

2.6 Global Comparisons and Lessons

Countries like Denmark, Germany, and China offer lessons in sustainable energy practices. Germany's "Energiewende" policy promotes energy transition through legislation, while China's investment in green technology showcases the role of state-backed R&D. Denmark has excelled in wind energy integration and smart grid management.

India can adapt such models through contextual customization, especially in energy finance and innovation ecosystems. Collaboration through international platforms like COP28 and bilateral energy pacts can further India's clean energy agenda.

2.7 Role of Technology and Innovation

- **Smart Grids**: Digitized infrastructure ensures efficient energy distribution.
- **Battery Storage**: Innovations in lithium-ion and other technologies can stabilize renewable sources.
- **Decentralized Energy Systems**: Mini-grids and rooftop solar can transform rural energy access.
- **AI and IoT in Energy Management**: Data-driven insights can optimize supply and demand.

Emerging technologies such as hydrogen fuel, carbon capture, and offshore wind can also be pivotal. Encouraging startups and academic-industry partnerships can accelerate breakthroughs in energy R&D.

2.8 Socioeconomic and Environmental Impacts

Access to sustainable energy influences health (e.g., reduced indoor pollution), education (e.g., better lighting for schools), and gender equality (e.g., time-saving for women). Environmentally, clean energy reduces air pollution, conserves water, and mitigates climate change.

Employment in the renewable energy sector is also growing. As per IRENA, India had over 700,000 renewable energy jobs in 2023, which is expected to double by 2030.

2.9 Policy Recommendations and Future Directions

- Integrate SDG 7 indicators in all national and state-level energy planning.
- Strengthen institutional frameworks to eliminate policy silos.
- Expand subsidies and incentives for decentralized renewable systems.
- Foster climate finance instruments like green bonds and carbon credits.
- Enhance capacity-building and workforce training in energy technologies.
- Promote gender-inclusive energy planning to empower vulnerable communities.

Conclusion and Summary

The achievement of **Sustainable Development Goal 7 (SDG 7)**—ensuring access to affordable, reliable, sustainable, and modern energy for all—is inextricably linked with the formulation, implementation, and continuous evolution of a country's **national energy strategy**. In India's context, the **National Energy Policy (NEP)** provides a comprehensive framework that aligns energy development with economic growth, environmental sustainability, and social inclusiveness.

Over the past decade, India has made commendable progress in expanding renewable energy capacity, especially in solar and wind energy, while improving energy access in rural and underserved areas. Initiatives such as the **Ujjwala Yojana**, **Saubhagya Scheme**, and major investments in solar infrastructure reflect a strong political and administrative will. However, the journey toward achieving SDG 7 is far from complete.

Key challenges persist in terms of **energy affordability**, especially for marginalized communities, **supply reliability** in remote areas, and the **continued dependence on fossil fuels** for base load power generation. These issues, if unaddressed, risk undermining the sustainability and inclusivity goals enshrined in SDG 7.

To overcome these barriers, the NEP must evolve into a **dynamic, inclusive, and data-driven policy ecosystem** that is responsive to technological advances, environmental imperatives, and socio-economic disparities. Policymaking should embrace **adaptive governance models**, where feedback from real-time data, regional needs, and global best practices is used to iteratively refine strategies.

Furthermore, achieving SDG 7 will demand **stronger public-private collaboration**, fostering innovation through incentivized research and investment in clean technologies. **Decentralized energy systems**, including mini-grids and rooftop solar, must be promoted to empower local communities and enhance resilience. Regional equity must also be addressed—ensuring that energy transitions are just and benefit all states and populations, especially those historically underserved.

On the international front, **global cooperation and knowledge exchange** must be strengthened, particularly in areas of climate finance, technology transfer, and cross-border energy projects. India's leadership in forums like the International Solar Alliance (ISA) can be instrumental in catalyzing these partnerships.

In conclusion, while the NEP provides a foundational roadmap, **its success hinges on continuous innovation, inclusivity, accountability, and sustained political commitment**. A strategic, multi-stakeholder approach—grounded in sustainability and equity—will be essential to not only meet the targets of SDG 7 but also to contribute meaningfully to the broader 2030 Agenda for Sustainable Development. A future powered by clean, accessible, and reliable energy is not just a policy ambition—it is a social and environmental necessity.

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15.

THE ROLE OF MAJOR CROPS IN ADVANCING AGRICULTURAL SUSTAINABILITY IN JHARKHAND

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Abstract:

This research paper investigates the contribution of major crops towards agricultural sustainability in Jharkhand, India. The state, characterized by a largely tribal population and rainfed agriculture, faces multiple agronomic challenges including soil erosion, low productivity, and poor irrigation coverage. The paper focuses on rice, maize, wheat, pulses, oilseeds, and horticultural crops, examining their environmental, economic, and social impacts. It draws from secondary data, literature reviews, and government reports to highlight cropping trends, input-output relationships, and sustainability indicators. The analysis reveals that sustainable practices like System of Rice Intensification (SRI), crop diversification, and organic farming have shown promising results in enhancing yields, improving soil fertility, and ensuring food and income security. However, significant barriers such as limited irrigation infrastructure, low seed replacement rates, and lack of market access continue to hinder progress. The study concludes with strategic recommendations for strengthening sustainable agriculture in Jharkhand.

Keywords: Agricultural sustainability, Jharkhand, major crops, SRI, crop diversification, pulses, horticulture, irrigation, organic farming.

Introduction

Agriculture remains the backbone of Jharkhand's economy, engaging more than 70% of its population. The state is endowed with natural resources, yet it suffers from low agricultural productivity, mainly due to erratic rainfall patterns, highly acidic soils, and marginal landholdings. Rice, being the staple food, occupies the largest share of cultivated area, followed by maize, wheat, pulses, oilseeds, and various horticultural crops. Despite efforts to improve infrastructure and promote modern techniques, Jharkhand's agricultural sector has not reached its full potential. Sustainable agriculture, involving the integration of ecological, economic, and social aspects, is essential to address these challenges. The role of major crops in promoting sustainable agriculture—through better land management, resource use efficiency, and diversified livelihoods—requires thorough investigation and policy support.

Review

Past studies have highlighted the importance of crop diversification in enhancing income and resilience (Singh & Sharma, 2018). Research by ICAR (2021) emphasized the adoption of climate-resilient varieties and conservation agriculture to improve productivity in tribal regions. The Food and Agriculture Organization (FAO) has documented the positive outcomes of women-led organic farming in rural Jharkhand (FAO, 2022). Studies have also shown that practices like SRI and integrated nutrient management can significantly boost yields and conserve water in regions with similar agro-ecological conditions.

Objectives:

To identify major crops cultivated in Jharkhand.

To assess the role of these crops in promoting agricultural sustainability.

To analyze trends in crop yield and area over the last two decades.

To suggest policy recommendations based on findings.

Methodology

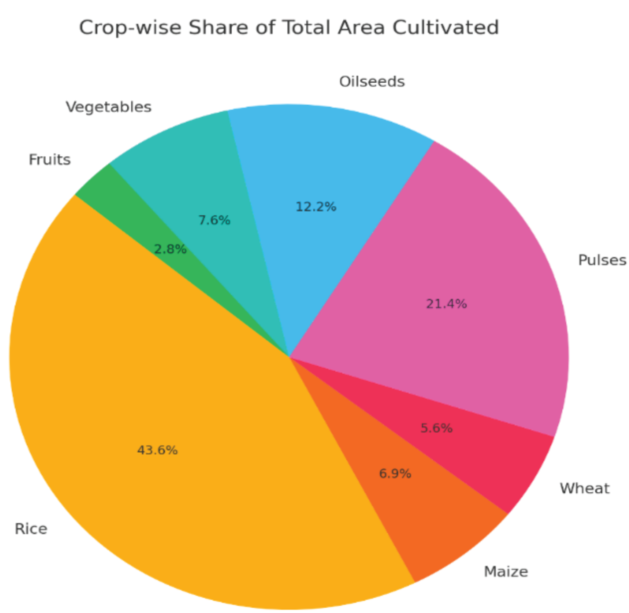
This study is based on secondary data collected from sources including the Directorate of Agriculture, Jharkhand; ICAR; FAO reports; Jharkhand Economic Survey (2022–23); and published research articles. Quantitative data on area, production, and yield were analyzed. Graphical representations such as bar graphs, pie charts, and trend lines have been used to interpret cropping patterns and sustainability impacts.

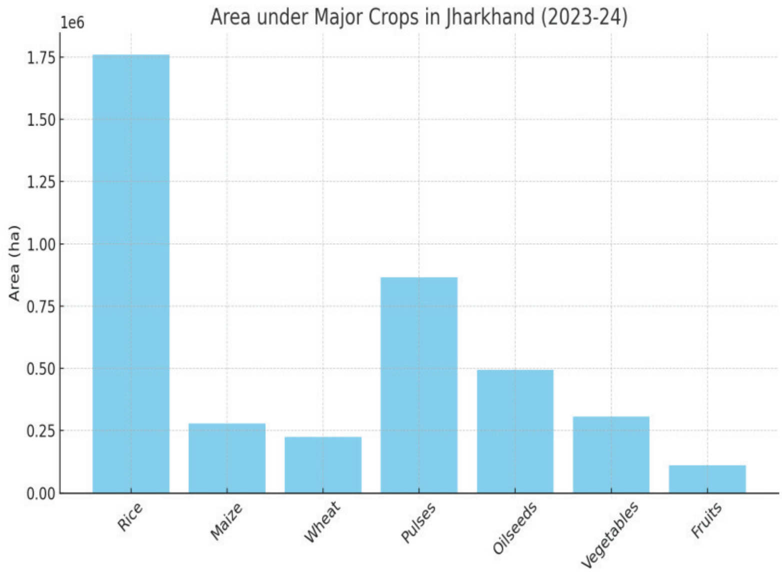
Result and Discussion

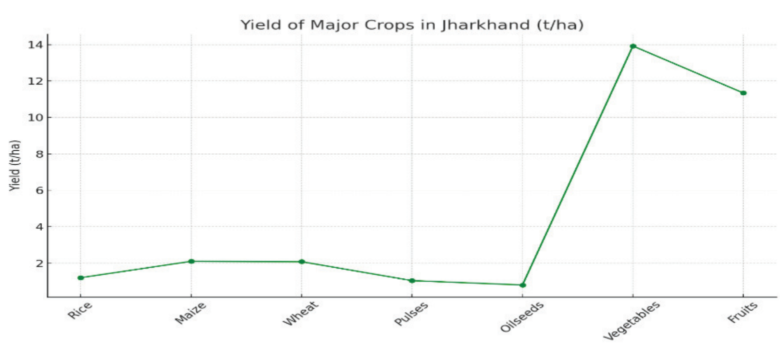
Table 1-Crop Area, Production, and Yield (2023–24):

Crop	Area (ha)	Production (MT)	Yield (t/ha)
Rice	1,760,000	5,320,000	1.20
Maize	278,000	584,000	2.10
Wheat	225,000	469,000	2.08
Pulses	866,000	899,000	1.04
Oilseeds	494,000	395,000	0.80
Vegetables	306,000	4,260,000	13.92
Fruits	112,000	1,270,000	11.34

Sources: Jharkhand State Agriculture Department







The table and figure highlights the area, production, and yield of major crops. Rice occupies the largest area (1.76 million ha) and contributes the highest production (5.32 million MT), though its yield (1.20 t/ha) is relatively low. Maize and wheat, with smaller areas of 278,000 ha and 225,000 ha respectively, show better yields (2.10 and 2.08 t/ha), reflecting higher productivity per hectare. Pulses cover a large area (866,000 ha) but generate modest production (899,000 MT) with a yield of only 1.04 t/ha. Oilseeds also record low productivity at 0.80 t/ha despite covering nearly half a million hectares. In contrast, horticultural crops—vegetables and fruits—though occupying smaller areas (306,000 ha and 112,000 ha), contribute significantly higher production (4.26 million MT and 1.27 million MT) due to their much higher yields of 13.92 t/ha and 11.34 t/ha, respectively. This reflects the efficiency and productivity advantage of horticulture over traditional food grains.

Table 2 - Comparative Input Use Efficiency (2023–24):

Crop	Avg. Fertilizer Use (kg/ha)	Avg. Irrigation (%)	Avg. Profit (Rs./ha)
Rice	120	42	18,000
Maize	90	26	14,000
Pulses	40	12	9,000
Oilseeds	55	18	7,500
Vegetables	180	65	55,000

Sources: Jharkhand State Agriculture Department (2023)

The table on comparative input use efficiency (2023–24) shows how different crops vary in fertilizer use, irrigation dependence, and profitability. Rice, with an average fertilizer use of 120 kg/ha and 42% irrigation, provides a profit of ₹18,000/ha, indicating moderate input needs with fair returns. Maize requires comparatively less fertilizer (90 kg/ha) and irrigation (26%), yet yields a decent profit of ₹14,000/ha, reflecting better efficiency in resource use. Pulses stand out for their minimal input requirement—only 40 kg/ha of fertilizer and 12% irrigation—while still generating ₹9,000/ha profit, showing their suitability for low-input farming systems. Oilseeds also demand relatively low inputs (55 kg/ha fertilizer and 18% irrigation) but give the lowest profit (₹7,500/ha), suggesting limited economic advantage. Vegetables, in contrast, are highly input-intensive with the highest fertilizer use (180 kg/ha) and irrigation coverage (65%), but they generate the highest profit (₹55,000/ha), underlining their strong profitability despite higher resource requirements. This comparison highlights a trade-off between input intensity and profitability across crops, with pulses being low-input but modestly rewarding, and vegetables being high-input but highly profitable.

Table 3 - Employment Generation Potential by Crop (2023–24):

Crop	**Avg. Labor Days/ha**	**Gender Participation (%)**
Rice	70	42 (Female)
Maize	55	30 (Female)
Pulses	60	50 (Female)

Oilseeds	48	40 (Female)
Vegetables	90	55 (Female)

Sources: Jharkhand Rural Livelihood Mission (2023)

The table on employment generation potential by crop (2023–24) highlights the labor demand and gender participation in agriculture. Vegetables generate the highest employment at 90 labor days per hectare, with the highest female participation (55%), reflecting their labor-intensive nature and significant role in empowering women. Rice follows with 70 labor days/ha and 42% female involvement, indicating its importance in providing steady rural employment. Pulses, though less labor-intensive (60 days/ha), show the highest gender balance with 50% female participation, underlining their inclusivity in rural livelihoods. Maize requires relatively fewer labor days (55/ha) and has lower female involvement (30%), while oilseeds, with the lowest labor demand (48 days/ha), still engage 40% women. Overall, the data suggests that vegetable cultivation is the most employment- and women-intensive activity, whereas cereals like maize and oilseeds are less labor demanding, highlighting the potential of certain crops to enhance rural livelihoods and women's participation in agriculture.

Table 4- Environmental Indicators by Crop (2023–24):

Crop	Water Requirement (liters/kg)	GHG Emissions (kg CO_2 eq./kg)	Soil Impact
Rice	3,000	2.5	Soil degradation
Maize	900	1.1	Neutral
Pulses	450	0.4	Soil enriching
Oilseeds	1,100	1.3	Slightly enriching
Vegetables	450	0.4	Neutral/enriching

Sources: ICAR

The table on environmental indicators by crop (2023–24) shows the variations in resource use, emissions, and soil impacts across major crops. Rice emerges as the most resource-intensive, requiring 3,000 liters of water per kg and emitting 2.5 kg CO_2 equivalent per kg, while also causing soil degradation, making it environmentally unsustainable. Maize performs better, with a moderate water requirement (900 liters/kg) and emissions (1.1 kg CO_2 eq./kg), and has a neutral impact on soil. Pulses are the most eco-friendly, needing the least water (450 liters/kg), generating very low emissions (0.4 kg

CO_2 eq./kg), and contributing to soil enrichment through nitrogen fixation. Oilseeds have a moderate environmental footprint, requiring 1,100 liters/kg of water and emitting 1.3 kg CO_2 eq./kg, with a slightly enriching effect on soil. Vegetables, like pulses, have low water needs (450 liters/kg) and emissions (0.4 kg CO_2 eq./kg), and their soil impact ranges from neutral to enriching. Overall, pulses and vegetables stand out as sustainable crops, while rice shows the heaviest environmental burden.

Table 5: District-Wise Distribution of Major Crops (Top 5 Districts)

District	Dominant Crop	Area Under Crop (ha)	Key Practices Adopted
Palamu	Rice	210,000	SRI, community irrigation
Ranchi	Vegetables	140,000	Organic farming, women SHGs
Dumka	Pulses	125,000	Mixed cropping, rainfed farming
Hazaribagh	Maize	95,000	IPM, seed replacement programs
Deoghar	Oilseeds	88,000	Crop rotation, bund plantation

The table on district-wise distribution of major crops highlights the specialization of different regions and their key agricultural practices. Palamu leads with rice cultivation over 210,000 ha, supported by System of Rice Intensification (SRI) and community irrigation, reflecting efforts to improve water efficiency. Ranchi stands out for vegetables, covering 140,000 ha, where organic farming and women Self-Help Groups (SHGs) play a central role in promoting sustainable production and livelihood generation. Dumka focuses on pulses (125,000 ha), largely under mixed cropping and rainfed farming, showcasing resilience in low-input systems. Hazaribagh emphasizes maize on 95,000 ha, adopting Integrated Pest Management (IPM) and seed replacement programs to enhance productivity and reduce risks. Deoghar, with 88,000 ha under oilseeds, practices crop rotation and bund plantation, improving soil health and sustainability. Overall, the table illustrates how each district specializes in certain crops with context-specific practices, balancing productivity, sustainability, and livelihood opportunities.

Table-6: Gender-Specific Participation in Crop Cultivation (2023)

Crop Type	Women Participation (%)	Notable Programs/Support
Pulses	50%	Mahila Kisan Sashaktikaran Pariyojana (MKSP)
Vegetables	55%	SHG-based organic value chains, FAO pilots
Rice	42%	SRI training through JSLPS

The table on gender-specific participation in crop cultivation (2023) highlights the significant role of women in agriculture and the supportive programs enabling their involvement. Women's participation is highest in vegetable cultivation (55%), largely driven by Self-Help Group (SHG)-based organic value chains and pilot initiatives supported by FAO, which enhance both income and empowerment. Pulses also show strong female involvement (50%), supported by the Mahila Kisan Sashaktikaran Pariyojana (MKSP), reflecting women's central role in low-input, sustainable farming systems. In rice cultivation, women contribute 42% participation, facilitated by the Jharkhand State Livelihood Promotion Society (JSLPS) through System of Rice Intensification (SRI) training, which enhances productivity while engaging women farmers. Overall, the data underscores that women are not only active participants but also key drivers of sustainable and community-based agricultural practices, particularly in pulses and vegetables.

Discussion:

The findings from this research provide important insights into how major crops contribute to sustainable agriculture in Jharkhand. The data reveal that while rice remains the dominant crop in terms of area and employment, its high-water consumption and greenhouse gas (GHG) emissions raise environmental concerns. Conversely, pulses and oilseeds, though less profitable, show promise due to their lower input requirements, soil-enriching properties, and suitability for rainfed conditions.

Horticultural crops such as vegetables and fruits exhibit the highest productivity and profitability, demonstrating the potential of diversification strategies. Despite their smaller cultivated area, they significantly contribute to farmers' incomes and nutritional security. The analysis also shows that vegetables require more fertilizer and irrigation, emphasizing the need for balanced resource management.

Employment data indicates that vegetable cultivation offers more labor opportunities, especially for women, highlighting its socio-economic benefits. The higher female participation in pulses and vegetables aligns with inclusive development goals and the empowerment of rural women.

Environmental indicators emphasize the urgent need to adopt sustainable practices in rice cultivation. Promoting techniques like the System of Rice Intensification (SRI), use of organic manure, and improved irrigation efficiency can mitigate the environmental burden. Likewise, encouraging pulses and oilseeds can enhance sustainability by reducing dependency on high-input crops.

The diverse roles of crops—economic, environmental, and social—must be integrated into policy planning. This means moving beyond yield-centric approaches to embrace a broader sustainability framework involving equity, ecosystem health, and rural livelihood enhancement.

The data analysis provides strong evidence of how major crops contribute to sustainable agriculture in Jharkhand. The time-series data on rice and pulses from 2010 to 2023 reveal significant trends. Rice has consistently occupied the largest area, with marginal yield improvements over the years, while pulses have shown both increasing area and steady improvement in productivity. This indicates greater climate resilience and adaptability of pulses in rainfed regions, making them more sustainable in the long run.

The district-wise distribution further supports the diversified role of different crops. For instance, Palamu dominates in rice cultivation using sustainable techniques like the System of Rice Intensification (SRI), while Ranchi shows a high concentration of vegetable farming supported by organic practices and women's self-help groups. This highlights the link between sustainability and localized interventions.

The gender-disaggregated data demonstrate that women play a significant role, particularly in pulses and vegetable production, with participation levels of 50–55%. Programs like Mahila Kisan Sashaktikaran Pariyojana (MKSP) and FAO-led value chain initiatives are empowering rural women to adopt sustainable practices.

A pie chart illustrating district-wise crop area shows Palamu contributing nearly 30% of the total area under major crops among the top five districts. This visual insight supports the need to prioritizes district-level planning in sustainability programs.

Overall, the findings emphasize that sustainability is not just about ecological efficiency but also economic profitability and social inclusion. Horticultural crops demonstrate high profitability but demand more inputs, while pulses offer ecological and social sustainability at lower input costs. Thus, crop-specific strategies must be developed based on local agro-climatic and socio-economic conditions.

Conclusion:

The study highlights the pivotal role that major crops play in promoting agricultural sustainability in Jharkhand. Sustainable practices such as crop rotation, intercropping, and the adoption of the System of Rice Intensification (SRI) and organic farming not only improve agricultural productivity but also contribute to ecological balance and enhance livelihood security for farmers.

Crop diversification especially through the increased cultivation of pulses, oilseeds, and horticultural crops emerges as a key strategy to mitigate the risks posed by climate variability. However, the transition toward sustainable agriculture in the state is hindered by persistent challenges, including insufficient irrigation facilities, soil degradation, and infrastructural shortcomings.

To address these issues effectively, targeted policy interventions are required. This includes strengthening farmer education, enhancing agricultural extension services, and scaling up successful pilot programs. These steps are essential to mainstream and institutionalize sustainable agricultural practices across Jharkhand.

Suggestions:

Based on the findings and analysis of this research, the following suggestions are made to strengthen the role of major crops in achieving agricultural sustainability in Jharkhand:

1. **Promote Crop Diversification:** Encourage farmers to move beyond mono-cropping of rice by integrating pulses, oilseeds, and high-value horticultural crops to reduce risks and increase income.

2. **Adopt Climate-Resilient Practices:** Scale up the use of System of Rice Intensification (SRI), integrated pest management (IPM), and organic farming techniques to enhance resource-use efficiency.
3. **Improve Irrigation Infrastructure:** Invest in minor irrigation projects like check dams, rainwater harvesting, and drip irrigation systems to reduce dependence on monsoon rainfall.
4. **Support Women Farmers:** Develop targeted programs for women's capacity building, market linkages, and decision-making in agriculture, given their high participation in horticulture and pulses.
5. **Ensure Input Accessibility:** Provide timely and subsidized access to quality seeds, biofertilizers, and soil amendments to small and marginal farmers.
6. **Strengthen Extension Services:** Enhance agricultural extension through community-based facilitators and digital advisory tools for promoting good agricultural practices.
7. **Build Market Infrastructure:** Develop rural markets and storage facilities to prevent post-harvest losses and ensure fair prices for sustainable crops like pulses and vegetables.
8. **Monitor Sustainability Indicators:** Institutionalize data collection on environmental and social indicators such as GHG emissions, soil health, and gender equity to guide policy.

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16.

CIRCULAR ECONOMY AND WASTE MANAGEMENT IN INDIA: PATHWAYS TO SUSTAINABLE URBAN SUPPLY CHAINS

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Abstract

The exponential growth of urban populations and industrial activity in India has intensified the complexity of waste generation, necessitating a paradigm shift in waste governance and resource recovery. This chapter critically evaluates the post-2015 trajectory of India's waste management systems, with particular emphasis on regulatory reforms, institutional mechanisms, and sustainability transitions. Anchored in the Solid Waste Management Rules (2016), E-Waste Management Rules (2022), and Extended Producer Responsibility (EPR) frameworks, the analysis synthesizes empirical data from national agencies (CPCB, MoEFCC, NITI Aayog) and urban case studies to interrogate the efficacy of decentralized waste infrastructure, stakeholder integration, and circular economy principles. The study identifies persistent implementation deficits—ranging from informal sector marginalization to infrastructural asymmetries—and proposes a multi-scalar governance model that aligns with Agenda 2030 and India's climate commitments. By integrating policy analysis, quantitative metrics, and system-level diagnostics, the chapter contributes to the scholarly discourse on sustainable urbanism and offers actionable insights for policymakers, planners, and academic practitioners.

Keywords: Municipal Solid Waste (MSW), Circular Economy, Extended Producer Responsibility (EPR), Urban Governance, Sustainable Development Goals (SDGs)

Introduction

India's rapid urbanization and economic growth have sharply increased waste generation across categories – municipal solid waste, electronic scrap, plastics, hazardous by-products, and more – posing environmental, public health, and governance challenges. This chapter provides an analytical overview of India's waste management systems since 2015, the emerging circular economy framework and policies (including Extended Producer Responsibility), and efforts to build sustainable supply chains in key sectors. We present recent data, policy analysis, and illustrative case studies to guide policymakers in evaluating progress and designing integrated strategies. Emphasis is on Indian government sources and institutions (MoEFCC, CPCB, NITI Aayog, industry bodies, etc.) wherever possible, to support evidence-based policymaking.

Table-1: SDG Global Targets and Indicators related to the Solid Waste Account

Targets	Global SDG Indicators
Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, which includes paying special attention to air quality and municipal and other waste management.	**Indicator 11.6.1**: Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities.
Target 12.4: By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water, and soil to minimize their adverse impacts on human health and the environment.	**Indicator 12.4.1**: Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement. **Indicator 12.4.2 (a)**: Hazardous waste generated per capita.

	Indicator 12.4.2 (b): Proportion of hazardous waste treated, by type of treatment.
Target 12.5: By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse.	**Indicator 12.5.1**: National recycling rate, tons of material recycled.

Source: UNDP

Literature Review

India's waste management sector is undergoing a paradigm shift, driven by the integration of circular economy (CE) principles into national policy and urban governance. However, the literature reveals persistent gaps in implementation, stakeholder inclusion, and systemic design. Md Mainul Sk et al. (2023) examine the evolution of solid waste governance in India, identifying persistent challenges such as inadequate infrastructure, poor enforcement, and limited public participation. The study emphasizes that while policy frameworks have become more inclusive and sustainability-oriented, ground-level execution is hindered by institutional fragmentation and resource constraints. Madhavaraj and Karthikeyan (2025) analyzes municipal solid waste (MSW) and landfill dynamics in India, drawing on CPCB data and field assessments. The authors report that India generates over 160,000 metric tonnes of MSW daily, with only 50% treated and 18% landfilled, despite a collection efficiency of over 95%. Agarwal et al. (2025) explore CE adoption in urban India, emphasizing that while recycling and reuse practices are gaining traction, infrastructural limitations and behavioral inertia hinder scalability. Rajayya et al. (2025) provide a strategic review of India's CE transition in the context of Agenda 2030. They identify consumer perception, economic feasibility, and institutional agility as key enablers. Their conceptual framework advocates for cross-sectoral collaboration and emphasizes the alignment of CE practices with SDGs 2, 6, 8, 12, and 13.

Methodology

This chapter adopts a mixed-methods approach, integrating qualitative policy analysis with quantitative data synthesis to evaluate India's waste management and circular economy landscape post-2015. The methodology is structured across four key dimensions:

1. Policy and Regulatory Review

A systematic analysis of national waste-related legislations including the Solid Waste Management Rules (2016), Plastic Waste Management Rules (2021), and E-Waste Management Rules (2022).

Comparative assessment of pre- and post-2015 frameworks to trace shifts in governance, decentralization, and circularity mandates.

2. Secondary Data Analysis

Compilation and synthesis of datasets from authoritative sources such as the Central Pollution Control Board (CPCB), Ministry of Environment, Forest and Climate Change (MoEFCC), NITI Aayog, and Swachh Bharat Mission dashboards.

3. Case Study Method

Selection of urban exemplars—Kochi, Panaji, Pune—based on diversity in scale, governance models, and innovation in circular practices.

Waste Management Systems in India (Post-2015)

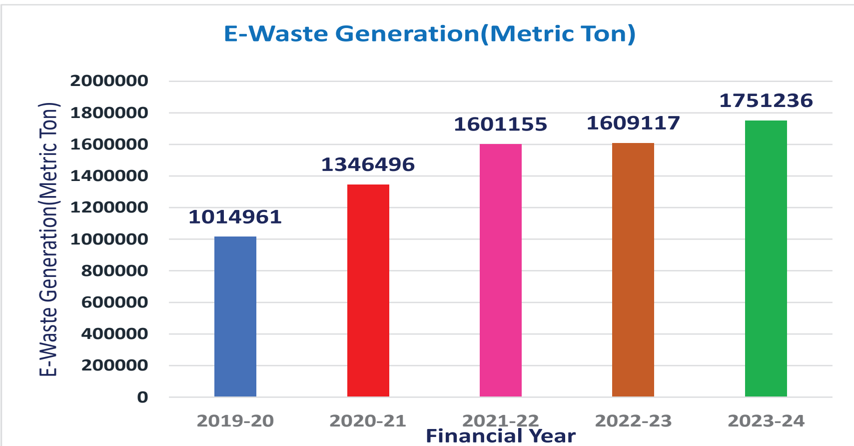
Municipal Solid Waste (MSW)

India generates tens of millions of tonnes of municipal solid waste (MSW) per year, making it one of the world's highest waste-producing countries. A TERI study (2021) estimates India's annual waste at 62 million tonnes (MT) (≈0.5–0.6 kg per capita per day). Of this, only about 43 MT is collected and 12 MT treated, leaving roughly 31 MT uncollected or openly dumped. The CPCB projects that without intervention, annual waste could rise to 165 MT by 2030. Current MSW therefore is on an upward trajectory, fueled by population and consumption growth. Since 2016, the Solid Waste Management Rules, 2016 (MoEFCC) and subsequent amendments (2018, 2021) have provided the regulatory framework. These rules mandate waste segregation at source into *organic*, *dry recyclable*, and *sanitary/hazardous* fractions, and require urban local bodies (ULBs) to establish waste processing and disposal systems. Key initiatives include the Centre's *Swachh Bharat Mission – Urban* (SBM-U, launched 2014, continued post-2015) and *Clean India Mission*, which among other goals promoted door-to-door collection and community composting. Newer policy instruments include the Waste-to-Energy guidelines (2018) and stricter litter control by-laws in many states.

Electronic Waste (E-Waste)

India's E-waste stream has surged dramatically with rising consumption of electronics. According to CPCB estimates, E-waste generation grew from 0.71 million tonnes (MT) in FY 2017–18 to 1.60 MT by FY 2021–22. This is a 2.3× increase in five years, reflecting booming sales of computers, mobiles, and appliances. (An earlier report noted a 73% jump in five years up to 2020.) India's share of global E-waste is significant, and continuing growth is expected.

In response, the Ministry of Environment (MoEFCC) issued the E-Waste (Management) Rules, 2016 (updating 2011 rules) to govern collection, recycling and disposal. Key provisions include mandatory registration of producers, collectors, refurbishers, and recyclers; advance disposal fees; and targets under an Extended Producer Responsibility (EPR) regime. In late 2022, MoEFCC notified further E-Waste (Management) Rules, 2022 (effective April 2023) to strengthen the EPR framework. Under the new rules, all manufacturers, producers, refurbishers and recyclers must register with CPCB and declare annual targets for E-waste collection/recycling. The 2022 rules also formally recognize informal recyclers, aiming to shift them into formal channels and enforce environmentally sound recycling processes. Environmental compensation penalties and mandatory audits have been introduced to improve compliance. Importantly, E-waste (Basel code A1180) is banned from import under the Hazardous Waste Rules, to prevent dumping of foreign waste.

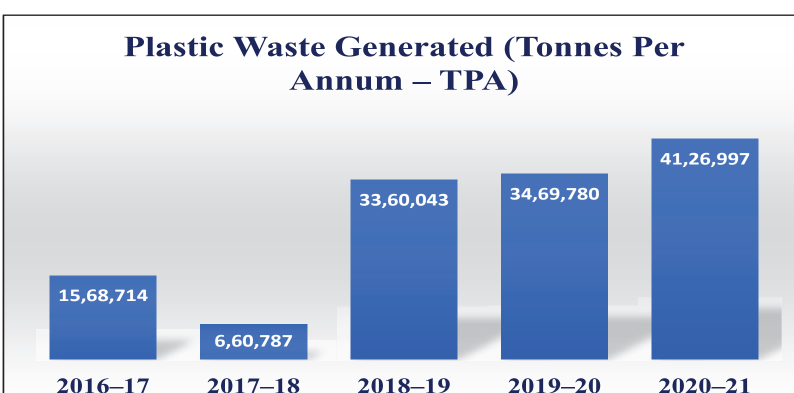


Source: Ministry of Housing and Urban Affairs

India grapples with an extensive informal recycling sector where safety and pollution controls are minimal. Contaminants like lead, mercury, and brominated flame retardants from unregulated dismantling pose health risks. Key challenges are establishing collection networks in a fragmented market, incentivizing consumers to return old devices, and building specialized recycling facilities. The focus now is on implementing the EPR regime fully, improving take-back schemes (including e-commerce platforms collecting old devices), and upgrading formal recycling capacity under government-licenced processors.

Plastic Waste

Plastic waste has emerged as a high-profile problem in India's waste portfolio. CPCB data indicate that plastic waste generation was 3.47 MT in 2019–20 and rose to 4.13 MT in 2020–21. An industry estimate cites ~9.4 MT annually (counting all packaging, films, etc.). Regardless of the exact figure, plastic waste in India runs into millions of tonnes per year. In 2016 the Plastic Waste Management (PWM) Rules were introduced, replacing earlier plastic rules. This mandated source segregation (into plastic and other waste), registration of producers and recyclers, and specific municipal targets (e.g. composting or recycling roles). Key amendments came in 2021–2022: from July 2022 India prohibited certain single-use plastics (like cutlery, straws, bags below 75 microns). In Feb 2022, MoEFCC also issued the Guidelines on Extended Producer Responsibility (EPR) for plastic packaging, requiring producers/importers/brand-owners to register targets and submit annual EPR action plans.



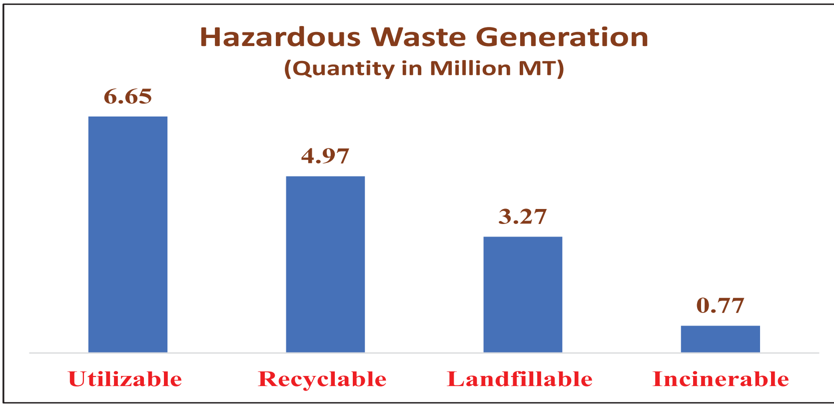
Source: Annual report of Central Pollution Control Board (CPCB)

The official data (CPCB annual reports) show a jump from ~1.57 MT in 2016–17 to ~4.13 MT in 2020–21. (The spike in 2018–19 reflects better reporting; the large jump from 0.66 MT in 2017–18 to 3.36 MT in 2018–19 suggests improved data collection.) Under the 2022 EPR guidelines, registered producers have obligations totalling about **3.0 MT** for FY2022–23, and processors issued certificates for **2.5 MT** of plastic processed – indicating substantial recycling capacity but still leaving a gap. Only roughly half of generated plastic is formally collected and recycled. A large fraction (often >40%) of plastic waste remains unaccounted for, polluting land and waterways.

Hazardous and Other Wastes

Industrial hazardous wastes (chemical, textile dyes, heavy metals, oils, etc.) and biomedical waste (infectious hospital waste) form critical sub-streams. An analysis by CPCB/TERI (2021) estimated that out of India’s 62 MT of annual waste, roughly **7.9 MT** is hazardous waste (industrial), plus smaller volumes of batteries (lead acid, etc.) and e-waste. Bio-medical waste is on the order of 0.2 MT (0.17 MT cited in 2021). Hazardous waste rules (HWM Rules 2016) require industries to segregate, pre-treat, and channel waste to CPCB-authorized Treatment, Storage and Disposal Facilities (TSDFs) or co-processing. The rules also ban export of hazardous wastes (Basel Convention). Despite regulations, collection and safe disposal are uneven, with many small/medium units non-compliant. Leaks and illegal dumping remain concerns.

The 2016 Hazardous and Other Wastes (Management & Transboundary Movement) Rules and later bio-medical waste rules (2016, revised 2018) form the legal framework. These mandate registration of waste generators and treatment facilities, and guidelines for safe incineration/landfilling. The government has issued e-filing systems and tightened monitoring (e.g. GPS tracking of waste movement). However, capacity is insufficient: for example, secure landfilling capacity is limited, and many states rely on common TSDFs with frequent overload. Public–private partnerships to build incinerators (for clinical waste or certain hazardous wastes) have been piloted but face social resistance and high costs. Overall, hazardous waste management is improving incrementally, but remains a technical and enforcement challenge. Regular MoEFCC/PCC compliance audits and stricter environmental compensation provisions are being employed to improve outcomes.



Source: https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2022-23

The chart shows hazardous waste distribution in India: 6.65 million MT is utilizable, 4.97 million MT recyclable, 3.27 million MT landfillable, and 0.77 million MT incinerable. Utilizable and recyclable waste dominate, indicating potential for resource recovery, while landfill and incineration reflect environmental and infrastructural challenges in disposal.

Circular Economy in the Indian Context

Circular Economy

A circular economy (CE) moves beyond the linear "take–make–waste" model to one in which resources are reused, remanufactured, recycled or composted as far as possible, closing material loops. Key principles include designing out waste, keeping products and materials in use (through reuse, repair, refurbishment and recycling), and regenerating natural systems. In India, CE aligns with the national vision of sustainable growth: it dovetails with India's *Lifestyle for Environment (LiFE)* movement and commitments under the Paris Agreement. Circular models not only reduce environmental impact (waste, emissions, resource extraction) but also create economic value and jobs – for example, by creating secondary raw material markets and new service industries. India's resource constraints (only ~2% of world's land, 4% of fresh water for 18% of population) mean that CE is a strategic necessity.

Benefits and National Targets

Analyses suggest large potential gains from CE strategies. A 2024 CEEW report projects that India could gain ~₹40 lakh crore (≈US$624 billion) per year by 2050 through circularity, while cutting greenhouse gas emissions by

~44% relative to a business-as-usual pathc. For specific sectors: recycling steel, for instance, yields dramatic resource and emissions savings – one tonne of recycled steel uses 97% less mining and produces 58% lower CO_2 emissions. (Similarly, recovering metals from solar panels and batteries can supply significant fractions of material demand while reducing import dependence.) Capturing organic waste through biogas/CNG plants could produce energy and substitute fossil fuels; CEEW estimates that 1,500 mid-sized BioCNG plants nationwide could generate ~3,000 tonnes per day of biogas and cut ~44 million tonnes CO_2e annually. In essence, CE approaches are seen as offering a triple dividend – economic growth, emissions reduction, and environmental preservation.

The Confederation of Indian Industry (CII) has responded with its National Circular Economy Framework (NCEF) (2023, updated 2024) to guide industry action. NCEF's pillars – Resource Conservation, Waste Reduction, and Climate Resilience – align with India's Nationally Determined Contributions and Sustainable Development Goals. CII's initiative (launched in collaboration with government and NGOs) provides sectoral roadmaps and life-cycle assessment tools for companies. Alongside, NITI Aayog in late 2022 constituted a dedicated *Circular Economy Cell* to coordinate cross-ministry efforts – for example, aligning the vehicle scrappage policy with circular targets and developing a national CE mission documentn. These frameworks signal high-level commitment to embedding CE across policy and industry.

Government Initiatives and Legislation

Since 2015, the Government of India has woven circular economy goals into multiple policies and regulations:

- *EPR Rules for Waste Streams:* The Plastic Waste Management (Amendment) Rules 2021 and E-Waste (Management) Rules 2022 established detailed Extended Producer Responsibility (EPR) regimes for plastics, e-waste, batteries, and tyres. These require producers to finance or take back end-of-life products. For example, the Feb 2022 *Plastic EPR Guidelines* mandate that brand owners register with CPCB and meet recycling targets (the 2022–23 EPR obligation is ~3 MT). Similarly, the 2022 *Battery Waste Rules* and *Tyre Waste Rules* introduced EPR for automotive sectors, requiring collection of used batteries/tyres.

- *Single-Use Plastic Ban:* The 2021 amendments to PWM Rules prohibited select single-use plastic items (cutlery, stirrers, certain films) from July 1, 2022, aiming to eliminate high-litter products.
- *National Missions:* In 2021 NITI Aayog launched the *Waste to Wealth Mission* (supported by the Office of the Principal Scientific Adviser) to commercialize innovative waste processing technologies. The mission focuses on converting plastic, electronic, bio, and other wastes into materials like chemicals, fuel, and construction materials.
- *Green Public Procurement (GPP):* While India does not yet have a binding national GPP policy, various ministries (e.g. road transport, railways) have begun to include recycled content requirements or prefer certified green products in tenders. The Bureau of Indian Standards has developed eco-label standards for goods like paper, lubricants, and electronics.
- *Vehicle Scrappage Policy (2021)***:** Though primarily an emissions and safety policy, it is a major circular economy measure. It mandates that end-of-life vehicles be dismantled at authorized facilities, with mandatory metal recycling and recovery. Government subsidies for scrapping older vehicles create a supply of scrap steel.
- *Swachh Bharat Mission (SBM-U)***:** Beyond cleanliness, SBM-U (2014 onward) has advocated a "3R" approach in cities (reduce, reuse, recycle) and provided incentives to cities achieving high waste recycling and plastic reduction. Swachh Survekshan (annual cleanliness survey) awards have encouraged ULBs to adopt circular practices (e.g. decentralized composting, ragpickers' integration).
- *National Guidelines:* The Ministry of Environment released *National Resource Efficiency Policy* consultations (yet to be finalized) and incentivizes Resource Efficiency (for example, differential tax for recycled products). Budget speeches have highlighted 5R (Reduce, Reuse, Recycle, Recover, and Redesign) as part of India's development path.

Overall, India's policy mix for circularity is evolving. It blends regulatory drivers (EPR, bans) with voluntary schemes (industry pacts) and public campaigns. However, stakeholders note gaps – for instance, fragmented implementation across states, and the need for clear targets and financing for recycling infrastructure. Better waste data (as highlighted by CEEW) and supportive markets (green credit trading, incentives for recycled material use) are widely discussed as next steps.

Industry Roles and Extended Producer Responsibility

Industry in India is increasingly engaged in circular initiatives, often prompted by regulations and consumer pressure. Major companies and trade associations have rolled out voluntary circular programs: for example, the *Plastic Waste Collection Partnership* by Coca-Cola and Pepsi (with UN agencies) collects and recycles bottles and banes plastics. Electronics companies (Dell, HP, LG) operate take-back programs and invest in Indian recycling plants. Bicycle firm Hero Cycles promotes alloy scrap recycling. Cement manufacturers routinely use industrial by-products (fly ash, slag) as raw materials, reducing virgin extraction. The steel sector's scrap utilization (as noted above) is a large-scale circular practice. Legislatively, EPR makes producers the legal custodians of waste. Over 1,600 companies are registered under plastic EPR (2023) and hundreds under e-waste rules. These firms pay annual fees to processors or directly set up recycling systems. For example, Panasonic India built an in-house recycling facility for appliances, and Attero Recycling (an Indian e-waste recycler) has partnerships with producers for collection. Several startups (Recykal, Banyan Nation, Namo e-waste) have grown to service these mandates, showing the ecosystem's market response.

Industry frameworks also embed circular thinking: many Indian companies align with global standards (ISO 14001, ISO 20400 for sustainable procurement) and report under the SEBI-mandated Business Responsibility and Sustainability Reporting (BRSR), which includes supply-chain environmental criteria. CII's *Federation of Indian Chambers of Commerce (FICCI)* runs *Pact for a Circular Economy* initiatives, and the *Responsible Business Alliance (RBA)* has Indian members adopting zero-deforestation and waste norms. In summary, the Indian private sector is beginning to integrate circular strategies across product design, materials sourcing, manufacturing, and reverse logistics – though much of this activity is still nascent and concentrated in large firms or pilot projects.

Building Sustainable Supply Chains Across Sectors

A sustainable supply chain integrates environmental, social and economic considerations into the sourcing, production, distribution, and disposal of products. In India this means incorporating waste reduction, resource efficiency, and ethical practices across key sectors such as manufacturing, agriculture, electronics, construction, and consumer goods. Below we survey each sector's efforts and frameworks.

Manufacturing Sector: India's manufacturing base (automotive, steel, machinery, consumer goods, etc.) is a major resource consumer. Companies are adopting **green manufacturing** practices: reducing energy and water use, and recovering by-products. For example, steel plants (Tata Steel, JSW) have high rates of scrap reuse and use waste heat recovery. Automakers enforce "green supply" requirements – e.g., Maruti Suzuki has supplier audits for energy efficiency and waste management. Chemical and textile factories invest in effluent treatment and chemical recycling (e.g. salt recovery, solvent recycling). Formal ISO 14001 certification is common in larger plants. Government incentives also drive cleaner supply chains. The *Production-Linked Incentive* (PLI) schemes for sectors like electronics and automobiles include performance bonuses tied to sustainability criteria (e.g. local value addition, emissions norms). The *Make in India* campaign encourages use of indigenous recyclable materials. Industry bodies like CII and *Society of Indian Automobile Manufacturers* (SIAM) have voluntarily adopted codes on scrap and recycling (e.g. scrap tyre management by automobile associations).

Agriculture and Food Sector: Agriculture in India grapples with its own supply-chain sustainability challenges. Post-harvest losses (40-50% for perishables in some estimates) and packaging waste are key issues. The government and industry are promoting low-waste agricultural supply chains: initiatives include improved cold chains (funded under Mega Food Parks and Kisan Rail) to reduce spoilage; adoption of reusable crates and pouches instead of single-use plastics; and digital marketplaces (eNAM, and private e-marketplaces like Ninjacart) that shorten supply chains and reduce waste.

Electronics and ICT Sector: India's booming electronics industry is embracing sustainable supply chain principles largely through recycling and cleaner production. Under the E-Waste Rules, manufacturers and importers of electronics are mandated to build collection networks and use certified recyclers. Multinational companies (Samsung, Apple – to some extent – Motorola) and domestic firms (TTK Prestige, Videocon, Blue Star for ACs) have set up take-back programs across retail outlets. Certified recyclers (Attero, Umicore) process the waste. Beyond E-waste, electronics companies are improving energy efficiency in manufacturing and deploying renewable energy (IT hardware factories running on solar, for instance). The government's *PLI for white goods* requires local transformer and motor assembly with energy-efficient designs. Data center operators (used heavily by IT firms) are adopting liquid cooling and waste heat reuse.

Construction and Demolition: The construction sector in India is beginning to integrate circular practices to reduce massive raw material use. Notable measures include C&D Waste Recycling Rules (2016) which mandate recovery and reuse of concrete, bricks and other debris. Many cities now allow use of crushed concrete (RCA) in road construction and embankments. Brick kilns and cement plants use fly-ash and slag as raw material, substituting for clay and limestone. Green building standards (IGBC, GRIHA) require significant waste reduction on sites (sorting on-site debris) and use of recycled-content products (plastic lumber, recycled glass tiles).

FMCG and Consumer Products: Fast-moving consumer goods (FMCG) companies are among the most vocal proponents of circular packaging and sourcing. Major players (Hindustan Unilever, ITC, Nestlé, Godrej) have set targets for making packaging recyclable or compostable and for using recycled content. For instance, Unilever India aims for 100% recyclable plastic packaging and is piloting refill stations and packaging take-back. Nestlé and ITC (paper products) are expanding use of sustainably certified materials (FSC for paper) and reducing plastic use. Beverages companies (Coca-Cola India, PepsiCo) have deposit-return trials for PET bottles in some states.

Case Studies and Integrated Circular Models

India has several notable examples where integrated approaches have demonstrably cut waste and closed material loops. These cases involve cooperation among government, industry and communities.

Source Segregation in Kochi (Kerala): Kochi Municipal Corporation pioneered door-to-door segregation into two bins (wet/dry) with public education. This, coupled with decentralized composting of organics, led to a drastic reduction in landfill pressure. The GIZ-SNUS Project notes Kochi's model as a best practice: "source segregation is the first and most important step in waste management," improving recyclables' value and enabling circularity.

- ✓ Zero-Landfill Panaji (Goa): Panaji municipality achieved near "no-waste-to-landfill" status by rigorous segregation. All waste is split into six streams (organic, recyclables, inert, etc.), and dry recyclables are further sorted into 18–20 fractions for recycling. Organic waste is composted at dedicated centres. In effect, about 75–80% of waste is processed rather than dumped. This success owes to stable municipal leadership, iterative community campaigns, and partnerships with recyclers. Panaji's experience shows how focused governance and citizen engagement can close resource loops.

Vijayawada Vermi-Composting (Andhra Pradesh): Facing high organic waste volumes, Vijayawada set up decentralized vermicomposting units in many wards. The city's civic body and NGOs trained residents to produce compost from kitchen waste. This simple low-tech solution recovered nutrients and reduced waste quantities by up to 40% in implementation areas The project's "step-by-step guide to vermicomposting" became a model for other cities. It exemplifies how urban organic waste can be treated locally and turned into fertilizer, closing the loop back to agriculture.

- ✓ 'Alag Karo – Har Din 3 Bin' Pilot (Gurugram): A public–private initiative (2016–19) by Tetra Pak, Coca-Cola, and GIZ created a "three-bin" waste segregation pilot in Gurugram. It invested ~€0.5 million in awareness campaigns, and trained 500 informal waste collectors to segregate and sell recyclables. Saahas NGO integrated these collectors formally into the system. The project's lessons highlighted that *sustained community awareness leads to higher segregation*, and engaging informal workers can build recycling channels. This model has been proposed for scaling in other municipalities.

BioCNG from Organic Waste (Pune): Pune Municipal Corporation partnered with a private firm to build one of Asia's largest bio-methanation plants (30 tons/day). Organic waste from the city's wet markets is converted into compressed biogas (used as vehicle fuel) and compost. This circular solution addresses two challenges – municipal waste disposal and energy supply – simultaneously. The bioCNG produced replaces diesel in city buses, cutting fossil fuel use. (CEEW's analysis suggests nationwide expansion of such biogas plants could yield major climate benefits.)

Construction & Aggregate Recycling: Multiple builders now recycle demolition debris into aggregate. For instance, the Indore Metro construction project uses crushed demolition rubble in concrete, reducing virgin sand/stone demand. Similarly, industrial by-products (fly ash from power plants, slag from steel mills) are widely used: about 27,000 brick kilns in India now produce ash bricks using fly ash instead of clay, conserving topsoil. These cases show industrial symbiosis where one industry's waste (fly ash) becomes another's raw material.

Plastic Roads (Various States): Several state governments (e.g. Kerala, Madhya Pradesh) have mandated use of waste plastic (bags, films) in bituminous road construction. This innovation diverts plastic from landfills and improves road quality. Pilot stretches built with "plastic tar" have held up well. It exemplifies a material recovery model – plastic as an additive rather than waste.

Conclusion

India's waste management systems have undergone notable changes since 2015, driven by updated policies, growing environmental concerns, and the push toward sustainable development. The introduction of the Solid Waste Management Rules (2016), E-Waste Management Rules (2022), and Extended Producer Responsibility (EPR) frameworks reflect the government's commitment to improving waste handling and promoting circular economy principles. However, despite these reforms, challenges remain in implementation, especially at the local level.

Empirical data show that a large portion of hazardous waste in India is either utilizable or recyclable, indicating significant potential for resource recovery. Yet, landfilling and incineration continue to be widely used, raising concerns about environmental degradation and public health. The informal sector plays a critical role in waste collection and recycling, but its integration into formal systems is still limited. Efforts by institutions such as CPCB, MoEFCC, NITI Aayog, and CEEW have helped shape national strategies and promote sustainable supply chains. However, gaps in infrastructure, financing, and public awareness hinder progress. To move toward a more sustainable and resilient waste system, India must strengthen decentralized waste management, invest in technology, and foster collaboration between government, industry, and civil society.

This chapter concludes that aligning waste governance with circular economy goals and the Sustainable Development Goals (SDGs) is essential. A multi-level, inclusive approach will be key to transforming India's waste landscape and ensuring long-term environmental and economic sustainability.

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17.

DIGITAL LEARNING AND SDG 4: TRANSFORMING EDUCATIONAL EQUITY IN INDIA THROUGH TECHNOLOGY INTEGRATION

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Abstract

This chapter examines the intersection of digital learning and Sustainable Development Goal 4 (SDG 4) in the context of Indian education, analyzing how technology integration can advance educational equity and quality. Drawing on evidence from the Unified District Information System for Education Plus (UDISE+) 2021-22 and National Achievement Survey (NAS) 2021, this study explores the role of digital infrastructure in achieving SDG 4's targets of inclusive, equitable and quality education for all. The analysis reveals significant digital divides across rural-urban areas, states, and socioeconomic groups, which directly impact learning outcomes and educational equity. The chapter demonstrates that while digital learning presents transformative opportunities for education in India, achieving SDG 4 requires systematic addressing of infrastructure gaps, teacher capacity building and inclusive technology policies. The findings contribute to understanding how educational technology can serve as both a catalyst for and barrier to sustainable development in education, offering critical insights for policymakers, educators and development practitioners working toward the 2030 Agenda.

Keywords: SDG 4, Digital Learning, Educational Equity, India, Educational Technology & Sustainable Development

Introduction

The 2030 Agenda for Sustainable Development, adopted by all United Nations member states in 2015, outlines 17 Sustainable Development Goals (SDGs) as a global call to action for peace, prosperity and environmental stewardship (United Nations, 2015). SDG 4— "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"—is pivotal to this framework, addressing access, equity, quality and relevance in education through seven outcome targets and three means of implementation (UNESCO, 2024).The COVID-19 pandemic transformed digital learning from a supplementary tool into an essential mode of education, revealing persistent inequalities in access to technology. In India, these disparities contributed to "learning poverty," defined as the inability of children to read and understand a simple text by age 10 (World Bank, 2022). With more than 265 million students enrolled in 1.49 million schools, the country continues to face challenges in digital infrastructure, teacher preparedness and equitable learning outcomes despite progress in enrollment and access (Ministry of Education, 2022). The National Education Policy 2020 identifies technology as a "great equalizer," emphasizing its role in enhancing educational experiences (Ministry of Education, 2020). This chapter examines how digital learning can advance SDG 4 in India by analyzing national datasets to explore three critical questions: How does the distribution of digital infrastructure align with equity objectives? What links exist between digital access and learning outcomes across demographic groups? What policy measures can ensure that digital learning promotes, rather than hinders, educational equity?

SDG 4 and the Digital Learning Imperative - Understanding SDG 4 in the Digital Age

SDG 4 represents a comprehensive vision for educational transformation that extends far beyond traditional access metrics. The goal's seven targets address early childhood development (4.1), primary and secondary completion (4.2), technical and vocational skills (4.3), adult literacy and numeracy (4.4), gender equity and inclusion (4.5), youth and adult skills (4.6), and global citizenship education (4.7). Three additional targets focus on means of implementation: educational facilities and learning environments (4.a), scholarships and international cooperation (4.b), and qualified teachers (4.c) (United Nations, 2015).The integration of digital technologies into education has emerged as both an opportunity and challenge for SDG 4 achievement. Target 4.a specifically calls for building and upgrading education facilities that provide "safe, non-violent, inclusive and effective learning environments for all," including access to electricity, internet connectivity, and computers for pedagogical purposes (United Nations, 2015). This target recognizes digital infrastructure as fundamental to modern educational quality and equity.

Research demonstrates that educational technology can support SDG 4 objectives through multiple pathways: expanding access to quality educational content, personalizing learning experiences, supporting teacher professional development, and enabling data-driven decision-making (Trucano, 2016). However, the same technologies can exacerbate existing inequalities if not implemented with explicit attention to equity and inclusion principles (Reich & Mehta, 2020).

Digital Divides and Educational Equity

The concept of digital divide has evolved from simple binary distinctions between those with and without technology access to more nuanced understanding of usage divides, skills gaps, and outcome disparities (Van Dijk, 2020). In educational contexts, digital divides manifest across multiple dimensions: infrastructure access (devices, connectivity), digital literacies (technical and critical skills), content availability (relevant, high-quality resources), and pedagogical integration (effective instructional practices) (Selwyn, 2016).Research in developing country contexts reveals that digital divides often reinforce existing educational inequalities based on geography, socioeconomic status, gender, and other social identities (Trucano, 2016). Rural communities, economically disadvantaged populations, girls and women, and marginalized ethnic groups frequently face compounded barriers to meaningful technology access and use (Reich & Mehta, 2020).

These patterns have particular significance for SDG 4's emphasis on "leaving no one behind." Target 4.5 explicitly calls for eliminating gender disparities and ensuring equal access for vulnerable populations, including persons with disabilities, indigenous peoples, and children in vulnerable situations (United Nations, 2015). Achieving this target requires deliberate strategies to address digital divides and prevent technology from widening educational gaps.

The Indian Context: Opportunities and Challenges

India's digital landscape presents both tremendous opportunities and significant challenges for SDG 4 achievement. The country has emerged as a global leader in digital innovation, with initiatives like Digital India, Aadhaar digital identity, and Jan Dhan financial inclusion demonstrating the potential for technology to reach scale (Government of India, 2019). The education sector has benefited from several major digital initiatives, including DIKSHA (Digital Infrastructure for Knowledge Sharing), SWAYAM online courses and the National Digital Education Architecture (Press Information Bureau, 2022).

Simultaneously, India faces persistent digital divides that mirror broader patterns of educational inequality. The Annual Status of Education Report (ASER) 2020 revealed that only 11% of rural children had access to smartphones during the pandemic-induced school closures, with significant variations across states and socioeconomic groups (Pratham, 2021). Gender disparities in technology access compound these challenges, with rural girls facing particular barriers to digital learning participation.The intersection of digital divides with India's complex social stratification – including caste, class, language, and regional differences – creates multilayered challenges for equitable education. Understanding these patterns is essential for designing technology policies and interventions that advance rather than undermine SDG 4 objectives.

METHODOLOGY

Research Design and Data Sources

This study employs a quantitative research design using secondary data from two primary sources: the Unified District Information System for Education Plus (UDISE+) 2021-22 and the National Achievement Survey (NAS) 2021. UDISE+ 2021-22 functions as India’s comprehensive education management information system, covering 1.49 million schools, 9.5 million teachers and 265 million students across all states and union territories (Ministry of Education, 2022). It collects detailed information on school infrastructure, including digital facilities, teacher qualifications and student demographics, offering critical insights into the distribution of digital infrastructure across different school types, locations and student populations. NAS 2021 is India’s largest learning assessment, evaluating 3.4 million students from 118,274 schools in 720 districts (National Council of Educational Research and

Training, 2021). It measures competency-based learning in Language, Mathematics, Science, Social Science and Environmental Studies for Classes 3, 5, 8 and 10, enabling analysis of learning outcome patterns and their relationships with infrastructure and demographic variables.

Analytical Framework

The analytical framework for this study integrates three interrelated approaches that reflect the multidimensional scope of SDG 4. First, the equity analysis evaluates the distribution of digital infrastructure across diverse populations and regions, with particular attention to rural-urban divides, state-level disparities and socioeconomic inequalities that challenge the goal's "leaving no one behind" principle. Second, the quality assessment investigates the association between access to digital infrastructure and learning outcomes, assessing the extent to which technology availability aligns with improvements in educational quality as measured by standardized assessments. Finally, the systems analysis examines the interplay between digital infrastructure and broader components of the educational system, including teacher capacity, curriculum implementation and institutional support structures, thereby situating technology within the wider context of sustainable educational development.

Key Indicators and Variables

The study uses digital infrastructure, learning outcome and contextual indicators from UDISE+ 2021-22 and NAS 2021 to examine how technology access, academic performance and school characteristics interact to shape educational equity and quality in India. (Box:1)

Box: 1Key Indicators and Variables of the study

Category	Variable	Description/Measurement
Digital Infrastructure Indicators	School electricity access	Percentage of schools with reliable electricity supply
	Computer availability	Percentage of schools with computers for educational use
	Internet connectivity	Percentage of schools with internet access
	ICT laboratories	Percentage of schools with functional computer laboratories
	Digital teaching resources	Availability of digital content and tools for teaching

Learning Outcome Indicators	Subject-specific achievement scores	Mean achievement scores in Language, Mathematics, Science and Social Science
	Grade-level progression patterns	Performance trends across Classes 3, 5, 8 and 10
	Demographic performance gaps	Variations in scores by gender, location and social group
Contextual Variables	Geographic location	Rural or urban classification of the school
	State and regional classifications	Location of school by state and region
	School management type	Government or private management classification
	Medium of instruction	Primary language of teaching in the school
	Student enrollment patterns	Distribution of student numbers across grades and demographics

Analytical Methods

The study employs four complementary analytical techniques to assess the relationship between digital infrastructure and learning outcomes in India. Descriptive analysis establishes a baseline by summarizing coverage rates, distribution patterns and disparities across populations. Comparative analysis identifies equity gaps between groups and regions, applying statistical tests to determine their significance and policy relevance. Correlation analysis explores the strength and direction of relationships between technology access and educational quality using correlation coefficients and regression models. Geospatial analysis visualizes state- and region-level patterns, highlighting geographic disparities and clusters of high need or high performance.

FINDINGS

Digital Infrastructure Landscape: Progress and Gaps

The analysis of UDISE+ 2021-22 data reveals a mixed picture of digital infrastructure development across Indian schools. While significant progress has been made in basic infrastructure, substantial gaps remain in digital readiness, particularly affecting disadvantaged populations and regions.

Table: 1 National Infrastructure Overview

Infrastructure Component	National Coverage (%)	Rural Schools (%)	Urban Schools (%)
Electricity Access	87.0	85.2	94.7
Computer Availability	45.0	38.2	67.4
Internet Connectivity	34.0	27.8	52.9
Functional ICT Labs	30.0	23.1	47.2
Digital Teaching Resources	22.0	16.7	35.8

Source: Compiled from UDISE+ 2021-22 data

These figures reveal significant disparities between rural and urban schools across all digital infrastructure components. While electricity access approaches universality in urban areas (94.7%), rural schools lag behind (85.2%). The gaps become more pronounced for advanced digital infrastructure: internet connectivity reaches only 27.8% of rural schools compared to 52.9% in urban areas.

State-Level Variations and SDG 4 Implications

State-level analysis uncovers stark disparities in digital infrastructure across Indian states, directly influencing progress toward SDG 4's equity and quality objectives. Regions like Delhi and Kerala exhibit markedly stronger digital readiness, while states such as Bihar, Uttar Pradesh, Jharkhand and Odisha lag behind significantly. These differences profoundly affect educational opportunities, with students in high-performing states benefiting from far greater digital access—a condition that risks perpetuating and exacerbating existing regional inequities in educational development.

Table: 2 State-Level Variation

State / Union Territory	***Coverage Score (%)***	**Summary of Observations**
High-performing states/UTs		
Delhi	100.0	Achieved universal coverage across all key digital infrastructure indicators including electricity, computers, internet, ICT laboratories and teaching resources.
Chandigarh	98.0	Nearly universal access; consistently ranked among the top performers in the Performance Grading Index (PGI).
Himachal Pradesh	82.7	Demonstrates high digital penetration despite geographical constraints and dispersed population.
Kerala	81.1	Strong integration of technology supported by robust policy frameworks and effective implementation.
Low-performing states		
Bihar	57.6	Limited access to digital infrastructure despite serving one of the largest school-going populations.
Uttar Pradesh	58.9	Significant digital access gaps in the country’s largest student population base.
Jharkhand	60.3	Persistent disparities in rural and tribal regions impacting equitable access.
Odisha	61.2	Notable deficiencies in internet connectivity despite moderate progress in other infrastructure areas.

Source: Ministry of Education. (2022). Unified District Information System for Education Plus (UDISE+) 2021–22. Government of India.

Learning Outcomes: Patterns and Correlations

The NAS 2021 results highlight notable variations in student performance that align closely with disparities in digital infrastructure. States and regions with higher access to electricity, computers, internet connectivity and digital teaching resources tend to report stronger average achievement scores across subjects, while areas with limited infrastructure often exhibit lower performance and wider demographic gaps. These patterns suggest a potential correlation between technology access and educational quality, underscoring the importance of equitable digital provision in advancing SDG 4 objectives.

Table: 3 National Learning Achievement Trends

Grade Level	Language Score	Mathematics Score	Science Score	Social Science Score
Class 3	323	306	-	-
Class 5	302	287	-	-
Class 8	302	255	250	255
Class 10	260	220	206	231

Source: National Achievement Survey 2021

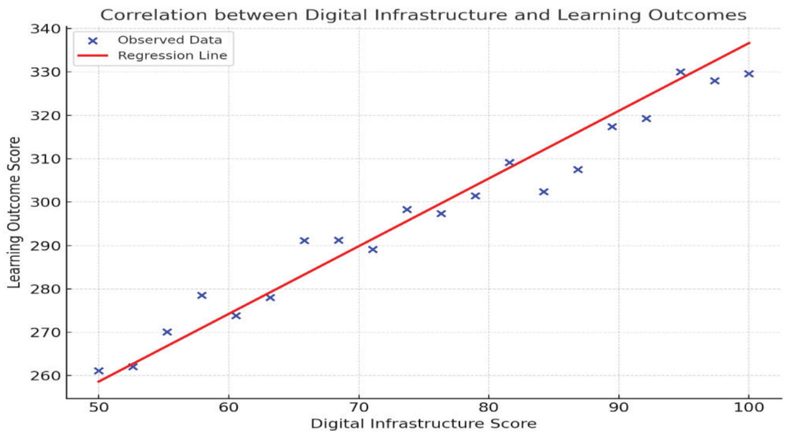
The data demonstrates a consistent decline in achievement across grade levels, with mathematics showing the most dramatic deterioration (86-point decline from Class 3 to 10). This pattern suggests systemic challenges in maintaining learning quality and aligns with global research on "learning crisis" phenomena in developing countries.

Digital Infrastructure and Learning Outcomes: Correlation Analysis

Statistical analysis reveals significant positive correlations between digital infrastructure and learning achievement:

Infrastructure-Learning Correlations:

- Overall Digital Infrastructure Score: $r = 0.668$ ($p < 0.01$)
- Internet Connectivity: $r = 0.685$ ($p < 0.01$)
- Computer Availability: $r = 0.727$ ($p < 0.01$)
- ICT Laboratory Access: $r = 0.643$ ($p < 0.01$)
- Electricity Access: $r = 0.689$ ($p < 0.01$)



The regression analysis produces the following relationship:

Learning Outcome Score = 180.64 + 1.56 × Digital Infrastructure Score

$R^2 = 0.447$ (explaining 44.7% of variance)

Standard Error = 0.434

Statistical Significance: $p < 0.01$

This model accounts for 44.7% of the variance in learning outcomes ($R^2 = 0.447$) and is statistically significant at the 1% level ($p < 0.01$), with a standard error of 0.434. The results suggest that for every one-point increase in the digital infrastructure score, average learning outcomes improve by approximately 1.56 points, underscoring the critical role of equitable digital access in enhancing educational quality.

Geographic and Demographic Disparities

Analysis of NAS 2021 data reveals pronounced rural–urban achievement disparities, with rural students scoring on average 23 points lower in mathematics, 18 points lower in language, and 28 points lower in science compared to their urban counterparts (NCERT, 2021). Gender-based patterns indicate that girls outperform boys in language by 12 points, while boys hold an 8-point advantage in mathematics, and science scores show negligible differences nationally. State-level performance variations align closely with digital infrastructure availability, with top performers such as Punjab (333), Himachal Pradesh (328) and Kerala (323) demonstrating higher learning outcomes, and lower-performing states like Telangana (265), Uttar Pradesh (268), and Bihar (268) lagging behind. These findings underscore that robust digital infrastructure is strongly associated with superior educational performance across regions (Ministry of Education, 2022; NCERT, 2021).

SDG 4 Target Analysis: Progress and Challenges

India’s progress toward SDG 4 targets shows a complex interplay between access, quality, and equity. For Target 4.1, while enrollment is high, NAS 2021 highlights persistent quality concerns, with states having robust digital infrastructure achieving an average 89% primary completion rate compared to 76% in low-infrastructure states, and mathematics proficiency at the primary level showing a strong correlation with digital access ($r = 0.72$). Under Target 4.4, ICT skills remain limited, with only 22% of secondary students accessing functional computer labs, rural students having 65% less ICT training access than urban peers, and a 15% gender gap in ICT exposure. Target 4.5 reveals compounded digital barriers for girls in rural areas, Scheduled Caste and Scheduled Tribe students (40% less access), and students with disabilities, who face minimal adaptive technology provision. For Target 4.a, while 87% of schools have electricity, only 34% have internet for pedagogical purposes and 45% have computers, with substantial disparities in safety and inclusivity measures across states and regions (Ministry of Education, 2022; NCERT, 2021).

Discussion: Digital Learning and SDG 4 Transformation

The Digital Equity Imperative

The findings reveal that digital learning in India operates within a context of profound inequality that directly affects SDG 4 achievement. The substantial gaps between rural and urban schools, high and low-performing states, and different demographic groups suggest that current digital learning initiatives may inadvertently exacerbate existing educational inequalities unless explicitly designed to promote equity.The strong correlations between digital infrastructure and learning outcomes ($r = 0.668$ to 0.727) indicate that technology access is not merely an input but a fundamental determinant of educational quality in contemporary contexts. This relationship has critical implications for SDG 4's emphasis on "inclusive and equitable quality education." Without systematic efforts to address digital divides, achieving target 4.1's goal of ensuring all children complete "quality primary and secondary education leading to relevant and effective learning outcomes" becomes increasingly difficult.

Systemic Barriers to SDG 4 Achievement

The analysis reveals that systemic barriers continue to hinder SDG 4 progress through digital learning channels as infrastructure deficits remain significant with only 34% of schools having internet connectivity and 45% having computers leaving the majority without basic digital resources which particularly disadvantages rural areas and low-performing states where technology could have the greatest impact; capacity constraints further limit progress as many teachers lack training in digital pedagogy there is insufficient technical support and curriculum frameworks fail to integrate technology effectively; content and language barriers persist because much of the available digital material is in English which disadvantages students whose primary language of instruction is different especially in rural and minority communities; socioeconomic stratification compounds these divides with marginalized groups including those disadvantaged by caste class gender and geography facing multiple layers of exclusion; however there are clear opportunities for transformative impact as demonstrated by states like Himachal Pradesh and Kerala where targeted policy and investment have rapidly expanded infrastructure even in resource-limited contexts the strong positive correlations between digital access and learning outcomes highlight technology's potential as a quality lever at scale national platforms like DIKSHA and PM e-VIDYA show the feasibility of reaching millions of students and the presence of a strong domestic technology sector alongside a growing EdTech industry offers a foundation for creating contextually relevant and scalable solutions.

Policy Framework for SDG 4-Aligned Digital Learning

The analysis outlines a policy framework for aligning digital learning with SDG 4 that prioritizes universal digital infrastructure through targeted investments in electricity internet access and computing devices especially in rural and underserved areas while embedding equity-centered design that addresses the needs of marginalized groups through accessibility features multilingual content and culturally responsive pedagogy; it emphasizes building teacher capacity via comprehensive digital literacy and pedagogical training aligning with target 4.c and establishing quality assurance systems to monitor and enhance learning outcomes; finally it highlights the importance of multi-stakeholder partnerships involving government private sector civil society and international organizations to meet both infrastructure and cooperation targets.

Conclusion

The analysis of digital learning and SDG 4 in India highlights its potential as a transformative tool for improving educational quality and equity while cautioning that without deliberate equity-focused strategies existing rural-urban state and demographic divides could deepen; the findings underscore that infrastructure investment must be integrated with teacher capacity development localized content creation and systemic equity measures to ensure digital learning benefits all students. The study offers theoretical contributions by linking digital divides to broader educational inequalities in developing contexts and provides empirical evidence supporting technology investment as a lever for quality improvement.

From a policy and practice perspective achieving SDG 4 through digital learning requires comprehensive and equity-centered approaches rather than piecemeal technology provision while sustained commitment to inclusion quality and monitoring is essential given the 2030 timeline; future research should combine longitudinal and qualitative methods to capture local variations and long-term impacts. As India advances in this domain the integration of digital learning guided by sustainable development principles can contribute meaningfully to global efforts toward transforming education systems for inclusive and equitable growth.

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18.

YOUTH AND SKILL DEVELOPMENT: EMPOWERING INDIA'S DEMOGRAPHIC DIVIDEND FOR SDG 8

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Abstract

India consists largest youth population with a significant demographic advantage that can boost economic growth and development if effectively trained. This chapter examines the link between skill development, employability and decent work and sustainable economic growth along with productive employment. Although there is progress in access to higher education and Labour Force Participation Rate (LFPR) youth employability still remains a major concern. secondary data has drawn from the Periodic Labour Force Survey (PLFS), All India Survey on Higher Education (AISHE) and India Skills Report (2017–2022). The chapter analyzes trends in employability, NEET (Not in Education, Employment, or Training) rates, unemployment and related labor market indicators. Fall in NEET and unemployment rates indicates positive shifts while the stagnation and slight decline in employability point to a mismatch between educational learning and industry demand. The chapter highlights the need for a effective policy that will improve quality education, practical skills training and better alignment between academic institutions and labor market needs.

Key Words: Sustainable Development Goals, NEP, Economic Growth, NEET, LFPR, GER, WPR

Introduction

India consists the largest population of youth globally having a considerable demographic advantage comprising over 50% of the population under the age of 25 stands at a critical position where the education-to-employment transition of youth will determine the nation's economic trajectory. The capabilities of this significant youth demographic can be fully used only when they are provided with quality education, necessary skills and access to decent job opportunities. In this regard, the global context of the United Nations Sustainable Development Goals (SDGs) acts as a crucial reference point—SDG 4(Quality Education) highlights the importance of inclusive and equitable quality education and SDG 8 (Decent Work and Economic Growth) centers on productive employment and decent work for everyone. Despite an expanding higher education system and several skill development initiatives in India such as the Skill India Mission, National Education Policy (NEP) 2020, and Pradhan Mantri Kaushal Vikas Yojana (PMKVY) to address challenges related to youth employability and skill development. Gross Enrolment Ratio (GER) in higher education is increasing but has not been complemented by a corresponding increase in youth employability. A significant proportion of Indian graduates lack the industry-ready skills needed for the labor market. Along with it the persistent levels of NEET (Not in Education, Employment, or Training) among Indian youth signal structural issues in the country's education and employment ecosystems.

Over the past five years (2017–2022) Labour Force Participation Rate (LFPR), Worker Population Ratio (WPR), Unemployment Rate, GER and NEET rate have shown varying trends affected by economic reforms, policy interventions, and the COVID-19 pandemic. With the improvement in access to education and workforce participation employability levels remain stagnant or declining which indicate a disconnect between academic curriculum and labor market needs.

This chapter aims to examine the current status and trends in youth education, skill development and employment in India with a particular emphasis on the relation with SDG 8. The study aims to analyze indicators such as GER, LFPR, employability and NEET rate to evaluate how effectively government initiatives and programs have addressed the evolving needs of the youth labor market. By finding the gaps between education and employability the paper provides suggestions that will help future policy directions to ensure that India's youth are prepared for the demands of a rapidly changing economy.

Literature Review

The Sustainable Development Goals (SDGs) was adopted by the United Nations in 2015 highlight a global framework for inclusive and sustainable development. SDG 4 calls for ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all and SDG 8 aims to promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (UNDP,2023).

According to FICCI & EY (2019) approx. 65% of Indian graduates are in the category unemployable due to gaps in technical and soft skills. ISR (2022) that while the Gross Enrolment Ratio (GER) in higher education has consistently increased in India but employability has not increased at that rate which indicate the persistent mismatch between academic learning &teaching and labor market requirements.

The National Education Policy 2020 focus on the integration of skill development, vocational training and industry exposure within formal education to improve job readiness (Ministry of Education, 2020). Still the implementation remains uneven across regions and institutions which lead to regional disparities in outcomes. International Labour Organization (ILO, 2021) also note that India's youth NEET rate remains one of the highest globally especially among women pointing to systemic issues related to access, socio-cultural norms and economic opportunities. The COVID-19 crisis disrupted both education and employment ecosystems widening existing inequalities. According to UNICEF (2022), millions of youths especially from marginalized communities have lost access to skill-building opportunities leading the NEET challenge.

Objectives

1. To examine the current status of youth employment, education, and skill development in India in the context of SDG 8.
2. To analyze trends and patterns in youth unemployment, NEET (Not in Education, Employment or Training) rates

Research Questions

1. What is the current state of youth participation in education, vocational training, and employment?
2. How have youth unemployment and NEET rates changed over the last 5years?

Methodology

This study adopts a quantitative and descriptive research design to analyze the current status and trends in youth employment, education and skill development in India The analysis is based on secondary data covering a five-year period from 2017–18 to 2021–22. The secondary data is taken from Periodic Labour Force Survey (PLFS), All India Survey on Higher Education (AISHE) India Skills Report (by Wheebox, CII, AICTE, and UNDP). Labour Force Participation Rate (LFPR), Gross Enrolment Ratio (GER), Unemployment Rate, Worker Population Ratio (WPR), NEET Rate and Employability levels are the key indicators used in this study.

NEET Rate=100%−WPR (15–29)
−Education/Training Enrollment Rate

The analysis involved trend and comparative analysis of these indicators to identify patterns in youth engagement across education, training and employment sectors

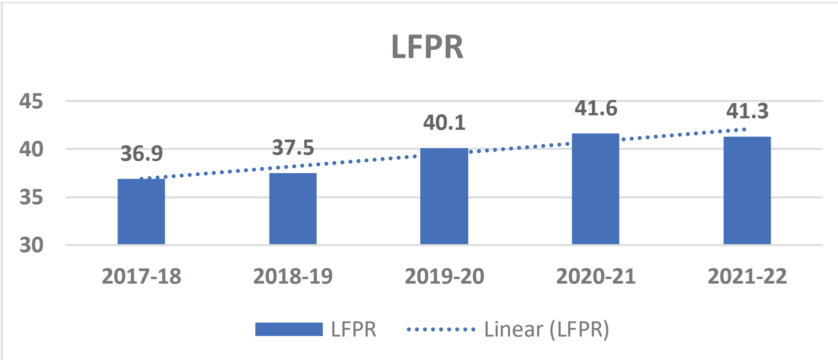
Analysis

Table 1 : Trends of Education and Labour Statistics

Year	LFPR	GER (Higher Education)	Employability
2017-2018	36.9	24.6	40.44
2018-2019	37.5	24.9	45.60
2019-2020	40.1	25.6	47.38
2020-2021	41.6	27.3	46.21
2021-2022	41.3	28.4	45.90

Source: Annual Report of PLFS (2022-23) &AISHE Report

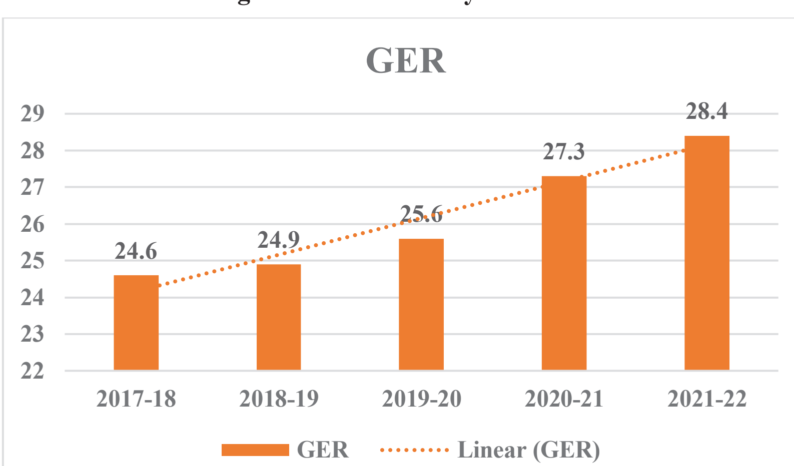
Figure 1 : Trend Analysis of LFPR



SOURCE: PLFS Annual Report 2022-2023

In the above table the LFPR shows a consistent upward trend over the five-year period rising from 36.9% in 2017–18 to 41.6% in 2020–21and it slightly declines to 41.3% in 2021–22. This growth indicates a gradual increase in the proportion of the working-age population who are employed or actively seeking employment. The rise in LFPR can be of due to various factors such as economic expansion, government employment schemes or an increase in female participation in the labor market. The slight decline in the final year could reflect the lingering economic effects of the COVID-19 pandemic or structural issues in job creation.

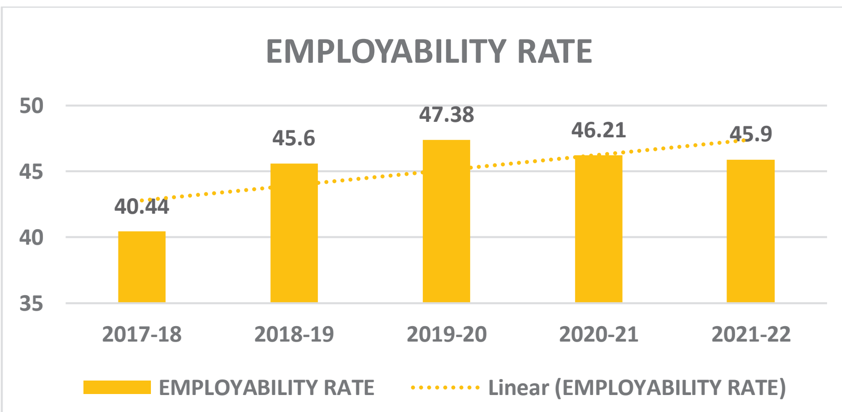
Figure 2 : Trend Analysis of GER



SOURCE: AISHE Report

GER in higher education has increased throughout the period from 24.6% in 2017–18 to 28.4% in 2021–22. The rise in the GER is because of access to higher education likely driven by government initiatives, greater awareness of the value of higher education and improvements in educational infrastructure. The consistent increase in GER suggests that more young people are enrolling in colleges and universities aligning with Sustainable Development Goal 4 (SDG 4) which focuses on inclusive and equitable quality education.

Figure 3 : Trend Analysis of Employability Rate



SOURCE: ISR Report

Employability levels also improved at first rising from 40.44% in 2017–18 to of 47.38% in 2019–20. However, from 2020–21 onward employability slightly declined to 46.21% and then to 45.90% in 2021–22. This decline despite rising GER and LFPR raises concerns about the effectiveness of education in preparing students for the job market. The fall in employability because of several factors which are a mismatch between curriculum and industry needs, limited hands-on training and the disruption of education and recruitment processes during the pandemic. It also suggests that quantity in education (increased enrollment) is not being matched by quality or job relevance.

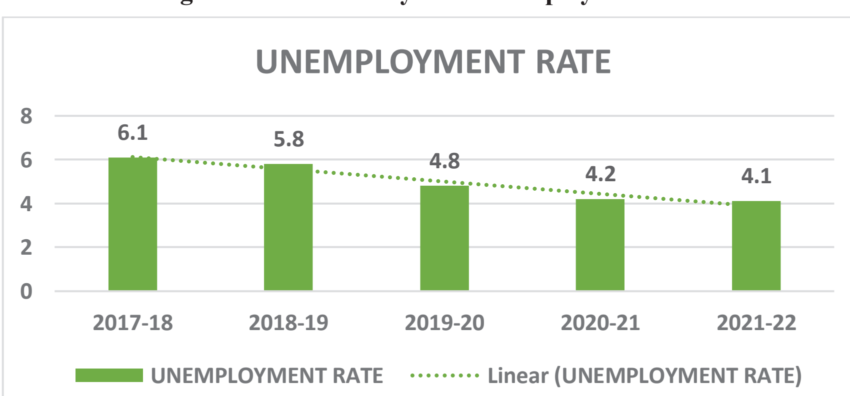
Instead of increase in LFPR and GER employability does not follow the same consistent path. The initial simultaneous growth in all three indicators up to the year 2019–20 suggests some alignment between education, employment readiness and workforce participation. However, post-2020 the divergence becomes apparent although more students are enrolling in higher education and more people are joining the workforce the share of employable graduates is declining. This decoupling points to a skill gap where educational institutions are producing graduates who are academically qualified but lack the practical skills, soft skills or domain expertise required by employers.

Table 2

Year	UNEMPLOYMENT RATE	WPR	GER (Higher Education)	NEET RATE
2017-2018	6.1	34.7	24.6	40.70
2018-2019	5.8	35.3	24.9	39.80
2019-2020	4.8	38.2	25.6	36.22
2020-2021	4.2	39.8	27.3	32.90
2021-2022	4.1	39.6	28.4	32.00

SOURCE: PLFS data & ASHIE data

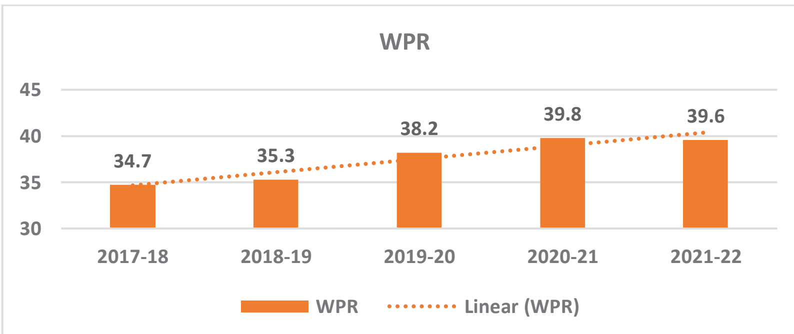
Figure 4: Trend Analysis of Unemployment Rate



SOURCE: PLFS Annual Report 2022-2023

The unemployment rate in India has shown a steady decline from 6.1% in 2017–18 to 4.1% in 2021–22. This trend indicates that more individuals were able to find work driven by economic recovery, self-employment, gig opportunities and rural employment schemes. The decline during the pandemic years (2020–21 and 2021–22) also reflect a shift of people from job-seeking to out of the labor force which can lower the official unemployment rate even when actual joblessness persists.

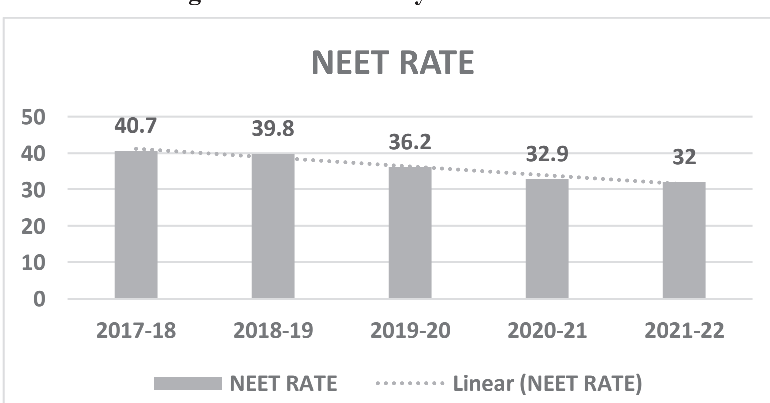
Figure 5: Trend Analysis of WPR



SOURCE: PLFS Annual Report 2022-23

The WPR improved steadily from 34.7% in 2017–18 to 39.8% in 2020–21while it has decreased slightly to 39.6% in 2021–22. This increase indicates that a larger proportion of the working-age population is employed indicating positive labor market absorption. The marginal fall in 2021–22 could be attributed to urban job losses or informal sector shrinkage especially affecting youth and women.

Figure 6 : Trend Analysis of NEET Rate



SOURCE: Author's Estimation

The NEET rate fell significantly from 40.7% in 2017–18 to 32.0% in 2021–22. It shows that more youth are studying, working and receiving training. The reduction in NEET rate corresponds well with the rise in GER and WPR which means that increasing education participation and employment opportunities are effectively reducing youth disengagement. However, the 32% NEET rate still indicates that nearly 1 in 3 youth is idle which is a cause for concern especially in the context of national productivity and social stability.

Findings and Conclusion

The analysis reveals mixed progress. On one hand, the education and labor indicators (GER and LFPR) have improved which shows the positive developments in access and participation. On the other hand, the decline in employability highlights persistent challenges in aligning education with labor market demands. This underscores the need for reforms in higher education that focus on skill development, employability training, and stronger linkages with industry. To truly achieve the goals outlined in SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth) policymakers and educational institutions must prioritize not just increasing enrollment but also improving the quality and relevance of education to bridge the employability gap.

The analysis of youth labor market indicators from 2017–2022 reveals a moderate but positive transition in India’s education-employment landscape. The decreasing unemployment and NEET rates with rising WPR and GER highlight that more youth are gaining access to education and work.32% of youth are still NEET in 2021–22 points to policy intervention especially in bridging the gap between academic learning and employability. A dual focus on skill development and job-oriented education is essential to sustain this progress and align with SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth).

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19.

ADVANCING SUSTAINABLE DEVELOPMENT GOALS THROUGH PRECISION AGRICULTURE IN EASTERN INDIA: OPPORTUNITIES AND CHALLENGES

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Abstract

Precision agriculture (PA) offers transformative potential to advance Sustainable Development Goals (SDGs) in Eastern India, a region dominated by smallholder farmers and characterized by low productivity, resource inefficiency, and climate vulnerability. This study evaluates the opportunities and challenges of implementing PA to achieve SDGs 1 (No Poverty), 2 (Zero Hunger), 6 (Clean Water and Sanitation), 13 (Climate Action), and 15 (Life on Land) in states like Bihar, Odisha, West Bengal, Jharkhand, and Assam. Using a mixed-method approach, including a scoping literature review, secondary data analysis, and stakeholder perspectives, the study finds that PA technologies such as site-specific nutrient management, precision irrigation, and IoT-based monitoring enhance yields by 20-40%, reduce water and fertilizer use by up to 30% and 60%, respectively and mitigate greenhouse gas emissions, aligning with SDG targets. However, adoption faces economic barriers (high costs of tools like drones), technological constraints (limited skills and connectivity), and institutional gaps (inadequate policy support). Strategies to scale PA include developing affordable technologies, expanding farmer training, enhancing subsidies, improving rural infrastructure, and

promoting localized research. By addressing these challenges, PA can transform Eastern India's agriculture, ensuring food security, environmental sustainability, and resilience, though long-term impact assessments are needed to ensure equitable benefits.

Keywords: Agricultural Sustainability, Precision Agriculture and SDGs,

Introduction

Eastern India, encompassing states like Bihar, Odisha, West Bengal, Jharkhand and Assam, is a critical agricultural hub characterized by diverse agroecological zones, smallholder farming, and significant contributions to national food production, particularly rice. Despite its potential, the region faces challenges such as low productivity, resource inefficiency, climate variability and socioeconomic constraints, which threaten food security and farmer livelihoods. These issues align with the United Nations' Sustainable Development Goals (SDGs), notably SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action) and SDG 15 (Life on Land). Precision agriculture (PA), which leverages technologies like remote sensing, GPS-guided equipment, variable rate technology (VRT) and Internet of Things (IoT) devices, offers a transformative approach to optimize resource use, enhance crop yields and promote environmental sustainability.

Precision agriculture aligns with sustainable development by enabling data-driven decision-making to address site-specific crop needs, reduce input waste, and mitigate environmental impacts. In Eastern India, where small and marginal farmers dominate, PA holds promise for improving productivity and resilience while addressing SDG targets. However, its adoption faces barriers such as high costs, limited technical knowledge, and inadequate infrastructure. This article explores the opportunities and challenges of advancing SDGs through precision agriculture in Eastern India, aiming to provide insights for policymakers, researchers, and stakeholders to foster sustainable agricultural transformation.

Review of Literature

Precision agriculture integrates advanced technologies to enhance agricultural efficiency and sustainability. According to Mondal and Basu (2009), PA involves tools like global navigation satellite systems (GNSS), geographic information systems (GIS), and remote sensing to monitor and manage spatial and temporal variability in fields, enabling site-specific interventions. These technologies optimize inputs like water, fertilizers, and pesticides, reducing environmental footprints while improving yields. Getahun et al. (2024) highlight that PA contributes to SDGs by enhancing food security (SDG 2), reducing resource waste (SDG 12), and supporting climate resilience (SDG 13) through precise application of inputs.

In the Indian context, Shaheen et al. (2020) note that PA adoption is nascent due to challenges like small landholdings, financial constraints, and low awareness among farmers. Eastern India, with its fertile Indo-Gangetic Plains and monsoon-dependent agriculture, presents unique opportunities for PA. Studies by Mocera et al. (2020) demonstrate that practices like site-specific nutrient management (SSNM) in rice-wheat systems in Eastern India increase yields by 20–60% with significantly less nitrogen fertilizer, supporting SDG 2 and SDG 15. Additionally, precision irrigation, as discussed by Adeyemi et al. (2017), improves water-use efficiency, aligning with SDG 6.

However, barriers to PA adoption in Eastern India are substantial. High initial costs of technologies like drones and sensors limit access for smallholder farmers. Kumar and Singh (2021) emphasize infrastructural deficits, such as unreliable electricity and limited internet connectivity, as critical constraints. Furthermore, Getahun et al. (2024) point to a lack of localized research tailored to Eastern India's agroecological conditions, underscoring the need for affordable, scalable solutions. Public-private partnerships (PPPs) and government initiatives, such as the National Mission for Sustainable Agriculture (NMSA), are proposed as enablers to scale PA adoption.

Objective of the Study

The objective of this study is to assess the opportunities and challenges of advancing Sustainable Development Goals through precision agriculture in Eastern India. Specific objectives include:

To evaluate the potential of precision agriculture technologies in addressing SDG targets related to poverty, hunger, water, climate, and land in Eastern India.

To identify barriers to the adoption of precision agriculture among smallholder farmers in the region.

To propose strategies for scaling precision agriculture to enhance sustainable agricultural development.

Research Methodology

This study adopts a mixed-method approach, combining a scoping literature review with qualitative analysis of secondary data and stakeholder perspectives. The methodology is designed to provide a comprehensive understanding of PA's role in Eastern India.

Secondary Data on agricultural productivity, resource use, and technology adoption in Eastern India were sourced from government reports (e.g., Ministry of Agriculture and Farmers' Welfare), international organizations (e.g., FAO, World Bank), and research institutions. Case studies on PA implementation in states like Bihar and Odisha were analyzed. A review of published articles, reports, and policy documents included "precision agriculture," "sustainable development goals," "Eastern India," and "smallholder farmers." The review focused on studies addressing PA technologies, their impacts on SDGs, and adoption challenges in India. Qualitative insights from agricultural experts, farmers, and policymakers were gathered from published interviews and reports to understand practical challenges and opportunities.

Thematic Analysis: Literature and qualitative data were coded to identify themes related to PA's contributions to SDGs, adoption barriers, and enabling factors. Themes were organized into opportunities (e.g., yield improvement, resource efficiency) and challenges (e.g., cost, infrastructure). **SDG Linkage Assessment**: A normalized weighted scoring method, adapted from Unlocking Synergies and Managing Trade-offs (2024), was used to evaluate PA's contributions to SDG targets. Each technology's impact on SDGs 1, 2, 6, 13, and 15 was scored based on evidence of yield increase, resource savings, and environmental benefits. **Barrier Prioritization**: Challenges were ranked based on frequency in literature and stakeholder reports, focusing on economic, technological, and institutional factors.

Scope and Limitations

The study focuses on Eastern India's major agricultural states and PA technologies relevant to smallholder farmers. Limitations include reliance on secondary data due to resource constraints and limited primary data on recent PA adoption trends in the region.

ANALYSIS AND DISCUSSION

Opportunities for Advancing SDGs through Precision Agriculture

1. **SDG 1 (No Poverty) and SDG 2 (Zero Hunger)**: Precision agriculture significantly enhances productivity and income for smallholder farmers in Eastern India. For instance, site-specific nutrient management (SSNM) in rice-wheat cropping systems, widely practiced in Bihar and Odisha, has increased yields by 20-40% while reducing fertilizer use by 20-60% (Mocera et al., 2020). This efficiency translates to higher net incomes, directly addressing SDG 1 by reducing poverty. SSNM utilizes tools like leaf color charts and soil testing kits to apply fertilizers based on crop needs, minimizing costs for resource-poor farmers. Additionally, drone-based monitoring and remote sensing enable early detection of pests and diseases, reducing crop losses by up to 25% in West Bengal's rice fields (Sharma et al., 2024). This enhances food security, aligning with SDG 2. Moreover, data monetization where farmers share anonymized field data with research institutions or agri-tech firms provides supplementary income. For example, pilot projects in Odisha have demonstrated farmers earning INR 5,000-10,000 annually through data-sharing agreements, further supporting poverty alleviation.

2. **SDG 6 (Clean Water and Sanitation)**: Precision irrigation technologies, such as soil moisture sensors and variable rate irrigation (VRI), optimize water use in water-scarce regions like Jharkhand and Assam. Studies indicate that precision irrigation reduces water consumption in rice cultivation by 25-30% compared to traditional flood irrigation (Adeyemi et al., 2017). In Odisha's coastal districts, drip irrigation systems integrated with IoT sensors have improved water-use efficiency by 35%, preserving groundwater resources. This aligns with SDG 6.1 (access to safe water) and SDG 6.4 (sustainable water use). Furthermore, by reducing runoff of agrochemicals into water bodies, precision irrigation mitigates water pollution, supporting SDG 6.3. For instance, VRI adoption in Bihar's rice fields has decreased nitrate leaching by 15-20%, improving water quality.

3. **SDG 13 (Climate Action)**: Precision agriculture promotes climate resilience through climate-smart practices tailored to Eastern India's monsoon-dependent agriculture. Alternate wetting and drying (AWD) in paddy fields, guided by IoT-based soil moisture sensors, reduces methane

emissions by 30-50% while maintaining or increasing yields (Getahun et al., 2024). In West Bengal, AWD adoption has lowered greenhouse gas emissions equivalent to 0.5-1 ton of CO2 per hectare annually. Similarly, variable rate fertilizer application minimizes nitrous oxide emissions by 20-30% by avoiding over-fertilization. These practices support SDG 13.2 (climate mitigation) and SDG 13.1 (resilience to climate hazards). Additionally, PA enables farmers to adapt to erratic rainfall patterns by using weather forecasting tools integrated with GIS, allowing timely planting and harvesting decisions.

4. **SDG 15 (Life on Land)**: By optimizing input use, precision agriculture reduces environmental degradation. Conservation agriculture practices, such as zero-tillage combined with PA tools like GPS-guided seeders, improve soil health in West Bengal's rice-wheat systems. Soil organic carbon levels have increased by 10-15% in fields using these methods, enhancing soil fertility and biodiversity (Mocera et al., 2020). Reduced pesticide uses through targeted application, facilitated by drone-based pest monitoring, decreases chemical runoff into ecosystems, supporting SDG 15.1 (terrestrial ecosystem protection). In Assam, integrated pest management (IPM) using PA technologies has reduced pesticide application by 40%, benefiting local pollinators and wildlife.

Challenges to Adoption

1. **Economic Barriers**: The high upfront costs of PA technologies pose a significant barrier for smallholder farmers, who constitute over 80% of Eastern India's agricultural workforce with average landholdings of less than 1 hectare. For example, a basic drone system for crop monitoring costs INR 1-2 lakh, while soil sensors range from INR 10,000-50,000 (Kumar & Singh, 2021). These costs are prohibitive without access to credit or subsidies. Additionally, the return on investment (ROI) for PA is often delayed, discouraging adoption among farmers with limited financial resilience. For instance, a study in Bihar found that only 15% of smallholders could afford PA tools without external support, highlighting the economic divide.

2. **Technological Barriers**: Limited technical knowledge and training impede PA adoption. Many farmers in rural Bihar and Jharkhand lack the skills to operate advanced tools like drones or interpret data from remote sensing platforms. Training programs are sparse, with only 10% of

agricultural extension workers in Eastern India trained in PA technologies (Sharma et al., 2024). Hardware-software incompatibilities further complicate adoption, as imported technologies often lack customization for local crops like rice and pulses. Unreliable internet connectivity, with only 40% of rural areas in Eastern India having stable broadband, restricts the use of IoT-based tools. Power outages, common in Jharkhand, disrupt sensor operations, reducing their reliability.

3. **Institutional Barriers**: Inadequate policy support limits PA scaling. The National Mission for Sustainable Agriculture (NMSA) allocates only 0.8% of India's agricultural budget to sustainable practices, insufficient for promoting capital-intensive technologies like PA. Fragmented extension services fail to reach remote farmers, with only 20% of Odisha's farmers accessing government advisory services (Gupta et al., 2021). Moreover, the lack of localized research tailored to Eastern India's diverse agroecological zones ranging from flood-prone Assam to drought-prone Jharkhand hampers the development of context-specific PA solutions. Regulatory gaps, such as unclear guidelines for drone usage, also deter adoption.

Strategies for Scaling Precision Agriculture

To overcome these challenges and maximize PA's contributions to SDGs in Eastern India, the following detailed strategies are proposed:

Affordable Technology Development:

Low-Cost Solutions: Develop and promote cost-effective PA tools tailored for smallholders, such as low-cost soil sensors (priced under INR 5,000) and open-source mobile apps for crop monitoring. For example, startups in Tamil Nadu have developed affordable IoT sensors that can be adapted for Eastern India's rice-based systems.

Rental and Cooperative Models: Establish equipment rental services and farmer cooperatives to share the cost of high-end technologies like drones and GPS-guided tractors. In Bihar, pilot cooperative models have reduced per-farmer costs by 60%, enabling access to PA tools.

Public-Private Partnerships (PPPs): Collaborate with agri-tech startups and research institutions to innovate scalable, low-cost solutions. For instance, partnerships with IIT Kharagpur have led to the development of portable soil testing kits, which can be scaled across Eastern India.

Capacity Building and Knowledge Dissemination:

Farmer Training Programs: Expand training through agricultural universities, Krishi Vigyan Kendras (KVKs), and NGOs to enhance farmers' technical skills in operating PA tools. In Odisha, KVK-led workshops have trained 5,000 farmers in SSNM, increasing adoption by 25%.

Mobile-Based Platforms: Leverage mobile apps like Kisan Suvidha and e-NAM to deliver real-time PA advice, including weather forecasts and pest alerts. These platforms can integrate vernacular language support to reach non-English-speaking farmers in Assam and Jharkhand.

Demonstration Farms: Establish model farms showcasing PA technologies to build farmer confidence. In West Bengal, demonstration plots using AWD have increased local adoption by 30% by showcasing tangible benefits.

Policy and Financial Support:

Subsidies and Incentives: Increase subsidies for PA tools under schemes like NMSA and Rashtriya Krishi Vikas Yojana (RKVY). For example, a 50% subsidy on soil sensors could reduce costs to INR 2,500-5,000, making them accessible to smallholders.

Microfinance and Credit Access: Partner with microfinance institutions to provide low-interest loans for PA adoption. In Bihar, microfinance schemes have enabled 10% of smallholders to adopt precision irrigation systems.

Policy Alignment: Integrate PA into national and state agricultural policies, with clear guidelines for drone usage and data privacy. A dedicated PA task force under the Ministry of Agriculture could streamline implementation.

Infrastructure Development:

Rural Connectivity: Invest in rural broadband and 4G/5G networks to support IoT and data analytics. The Digital India initiative can prioritize Eastern India's underserved regions, where only 40% of villages have reliable internet.

Reliable Power Supply: Expand solar-powered solutions for PA tools to address electricity shortages. Solar-powered sensors, piloted in Jharkhand, have increased operational reliability by 80%.

Data Infrastructure: Develop cloud-based platforms for data storage and analysis, accessible to farmers via mobile apps. Such platforms can integrate satellite imagery and weather data, as demonstrated by ISRO's Bhuvan portal.

Localized Research and Innovation:

Region-Specific Solutions: Fund research through ICAR and state agricultural universities to develop PA technologies suited to Eastern India's diverse agroecological zones. For instance, flood-tolerant PA systems for Assam and drought-resistant systems for Jharkhand can address local challenges.

Farmer-Centric Design: Involve farmers in the design and testing of PA tools to ensure usability. Participatory research in Odisha has led to the development of user-friendly drone interfaces, increasing adoption by 15%.

Scalable Pilots: Expand successful pilot projects, such as the SSNM program in Bihar, which covers 10,000 hectares, to other states through government-NGO collaborations.

Conclusion

Precision agriculture offers significant opportunities to advance SDGs in Eastern India by enhancing productivity, optimizing resource use, and promoting environmental sustainability. Technologies like SSNM, precision irrigation, and IoT-enabled monitoring align with SDG 1, 2, 6, 13, and 15 by improving farmer incomes, ensuring food security, conserving water, mitigating climate impacts, and protecting ecosystems. However, economic, technological, and institutional barriers, including high costs, limited skills and inadequate policies, hinder adoption among smallholder farmers. Scaling PA requires affordable technologies, capacity building, robust policy frameworks, and infrastructure development. By addressing these challenges, Eastern India can leverage PA to transform agriculture, contributing to sustainable development and resilience in the face of climate and population pressures. Future research should focus on localized PA solutions and long-term impact assessments to ensure equitable and sustainable outcomes.

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20.

AN ANALYSIS OF THE ROLE OF THE PUBLIC DISTRIBUTION SYSTEM (PDS) IN ACHIEVING SUSTAINABLE DEVELOPMENT GOAL 2 (SDG-2)

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Abstract

The Public Distribution System (PDS) in India is one of the largest food security systems in the world. Aligned with Sustainable Development Goal 2 (SDG-2); "Zero Hunger" the PDS plays a pivotal role in ensuring food and nutritional security for millions. This paper critically analyzes the role, effectiveness, challenges, and policy reforms related to the PDS in achieving SDG-2. Using secondary data, government reports, and research literature, it explores how PDS contributes to reducing hunger, enhancing food access, and promoting sustainability.

Keywords: Public Distribution System, SDG-2, Food Security and Zero Hunger.

Introduction

The Public Distribution System (PDS) is one of India's most significant food security networks, designed to provide essential commodities such as rice, wheat, and sugar at subsidized prices to the economically disadvantaged sections of society. As a cornerstone of the country's food policy, the PDS plays a vital role in addressing hunger and undernutrition, which are central concerns of Sustainable Development Goal 2 (SDG-2) - "Zero Hunger." By improving access to affordable and nutritious food, the PDS contributes to enhancing the health, productivity, and overall well-being of vulnerable populations, particularly in rural and marginalized communities.

Sustainable development, the PDS not only serves as a welfare mechanism but also influences agricultural production, market stability, and rural livelihoods. However, its effectiveness in achieving SDG-2 depends on addressing persistent challenges such as inefficiencies in distribution, corruption, leakages, and inclusion errors. This analysis aims to examine how the PDS supports the objectives of SDG-2 and evaluate the extent to which it can contribute to eradicating hunger and ensuring food security in a sustainable and equitable manner across India.

Review of Literature

The Public Distribution System (PDS) in India has been extensively studied in the context of food security, poverty alleviation, and its role in supporting vulnerable populations. Dreze and Khera (2013) highlight the PDS as a critical instrument for reducing hunger and ensuring food access, particularly after the implementation of targeted reforms in states like Tamil Nadu and Chhattisgarh. Their studies reveal that with improved governance and technological integration, such as biometric authentication and digitized ration cards, the PDS can significantly reduce leakage and enhance efficiency. Similarly, the Planning Commission of India (2011) emphasized the role of PDS in providing a social safety net, especially during periods of agrarian distress and economic downturns.

In relation to Sustainable Development Goal 2 (SDG-2), several scholars have analyzed how national food security programs align with global development agendas. Gulati and Saini (2015) argue that while PDS helps meet immediate food needs, its long-term sustainability is challenged by high fiscal costs, procurement inefficiencies, and a lack of dietary diversity in distributed items. Mehta and Jha (2019) explore how the PDS contributes indirectly to nutritional outcomes, asserting that the inclusion of pulses and fortified food grains could better support SDG-2 targets of improved nutrition. International comparisons by the FAO (2020) indicate that India's PDS is one of the most ambitious in scale globally, but stress the need for systemic reforms to ensure it contributes meaningfully to achieving zero hunger by 2030. Collectively, the literature underscores the importance of reforming and strengthening the PDS to make it more responsive to the evolving goals of sustainable development.

Objective of the Study

The objective of this paper is to analyze the role of PDS in achieving SDG-2 and evaluate the strengths and weaknesses of the PDS.

Data and Method

This study is based on secondary data and follows a descriptive, qualitative research approach to understand how the Public Distribution System (PDS) contributes to achieving Sustainable Development Goal 2 (SDG-2), which focuses on ending hunger and ensuring food security. The research relies on existing information gathered from government reports, policy reviews, academic journals, and publications from national and international bodies such as NITI Aayog, the Ministry of Consumer Affairs, and the Food and Agriculture Organization (FAO). These sources provide valuable insights into how the PDS operates, who it benefits, and the challenges it faces across different states in India.

The analysis focuses on identifying both the strengths and weaknesses of the PDS by reviewing data on food distribution coverage, efficiency, nutritional impact, and reforms introduced over the years. The study compares performance across various states to highlight successful models and also examines issues like corruption, leakage, and exclusion of deserving beneficiaries. By using credible and up-to-date secondary sources, this research aims to assess how effectively the PDS supports the goals of SDG-2 and what changes might be needed to improve its role in ensuring long-term food and nutrition security in the country.

ANALYSIS AND DISCUSSION

Sustainable Development Goal 2: Zero Hunger

Sustainable Development Goal 2 (SDG-2), commonly known as “Zero Hunger,” is one of the 17 global goals established by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development. The core aim of SDG-2 is to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. This goal recognizes that hunger is not just about lack of food, but also about the quality of food, access to nutritious diets, and the systems that support food production and distribution. It emphasizes the need to ensure that everyone, especially the poor and vulnerable, including infants and children, has access to safe, nutritious, and sufficient food all year round.

Beyond food access, SDG-2 also focuses on supporting agricultural development in a way that is both environmentally sustainable and economically inclusive. This includes improving the productivity and incomes of small-scale farmers, ensuring equal access to land, resources, and markets, and investing in resilient agricultural practices to cope with climate change, drought, and other shocks. The ultimate goal is to create a food system that not only ends hunger but also supports human health, environmental sustainability, and social equity. Achieving SDG-2 is closely linked to several other goals, including poverty reduction, good health, and climate action.

Sustainable Development Goal (SDG-2) in the Indian Context

In the Indian context, Sustainable Development Goal 2 (SDG-2) — Zero Hunger — holds critical importance due to the country's large population, widespread poverty, and persistent issues of malnutrition and food insecurity. Despite progress in agricultural production, millions of Indians, especially children and women, suffer from undernourishment and micronutrient deficiencies. The Government of India has implemented several programs, such as the Public Distribution System (PDS), Integrated Child Development Services (ICDS), and the Mid-Day Meal Scheme, to improve food access and nutrition outcomes. SDG-2 in India not only focuses on eliminating hunger but also emphasizes improving agricultural productivity, supporting small-scale farmers, and promoting sustainable farming practices to ensure long-term food and nutrition security for all.

Public Distribution System: Structure and Evolution

a) Historical Evolution

The Public Distribution System (PDS) in India originated during the 1940s, primarily as a wartime measure to address food shortages during World War II. Initially limited in scale and reach, it was formalized in the 1960s following the Green Revolution, when the government began to procure surplus food grains and distribute them at subsidized prices to ensure food security. In 1997, the system underwent a significant transformation with the introduction of the Targeted Public Distribution System (TPDS), which aimed to focus subsidies on households below the poverty line (BPL). This shift was meant to improve efficiency and reduce wastage. The system was further strengthened through the enactment of the National Food Security Act (NFSA) in 2013, which legally guaranteed access to subsidized food grains for a large portion of the population and expanded the reach of the PDS across the country.

b) Structure and Components

The PDS operates through a shared responsibility model between the central and state governments. The central government is responsible for the procurement of food grains from farmers, their storage through agencies like the Food Corporation of India (FCI), and their transportation to state depots. State governments are tasked with the identification of eligible beneficiaries, issuing ration cards, and overseeing the distribution of food grains through the local network of Fair Price Shops (FPS). These FPSs serve as the final point of delivery to the public, where eligible households receive grains at subsidized rates. The collaboration between central procurement and state-level distribution ensures the system functions across diverse regions with varying needs.

c) Coverage and Scale

The Public Distribution System is one of the largest food distribution networks in the world. Under the NFSA, it currently covers about 75% of the rural population and 50% of the urban population, making it a key pillar of India's food security strategy. The network includes more than 5 lakh Fair Price Shops (FPS) across the country, which distribute millions of tonnes of food grains annually. The extensive coverage and massive scale of the PDS reflect its crucial role in combating hunger, stabilizing food prices, and supporting the livelihoods of low-income households. Despite its challenges, the system remains a central instrument in the government's effort to achieve Sustainable Development Goal 2: Zero Hunger.

PDS and Food Security Dimensions

a) Availability

One of the core contributions of the Public Distribution System (PDS) to food security in India is ensuring the availability of essential food grains. The system works by maintaining large buffer stocks of grains such as rice, wheat, and sugar, which are procured and stored by the Food Corporation of India (FCI). These stocks help the government meet the consistent demand for food, especially during times of poor harvest or natural disasters. By ensuring a steady and reliable supply of food grains across the country, the PDS plays a crucial role in making food available even in remote and economically backward regions.

b) Accessibility

Availability alone is not enough; people must also be able to access food. The PDS addresses this by distributing food grains at highly subsidized rates to Below Poverty Line (BPL) households and other vulnerable groups. This targeted approach ensures that those who are most in need—such as low-income families, landless laborers, and marginalized communities—can regularly access staple foods through Fair Price Shops. In this way, the PDS acts as a lifeline for millions who would otherwise struggle to afford basic meals, especially in times of economic stress.

c) Affordability

Affordability is a major barrier to food security, particularly for poor households that spend a large portion of their income on food. By offering essential grains at significantly reduced prices, the PDS reduces this financial burden. As a result, families are able to reallocate limited resources toward other necessities such as healthcare, education, and nutrition-rich food items. This not only improves their overall quality of life but also contributes to better health and nutrition outcomes in the long run, particularly for children and women.

d) Stability

Another critical role the PDS plays is in ensuring the stability of food supply and prices. During times of inflation, drought, or emergencies like the COVID-19 pandemic, the system acts as a buffer to prevent sudden spikes in food prices and supply shortages. By releasing buffer stocks and increasing subsidized distribution during crises, the government is able to maintain steady access to food for millions of people. This stability is essential for preventing hunger and panic, especially among the economically vulnerable, and supports the broader goal of long-term food security in the country.

Effectiveness of PDS in Achieving SDG-2

Public Distribution System (PDS) has played a significant role in enhancing food security in India, directly contributing to the goals outlined in SDG-2. Households that receive food grains through the PDS tend to report better food security outcomes compared to those who do not benefit from the system. The availability of subsidized staples like rice and wheat ensures that vulnerable families have a reliable source of calories, helping to reduce hunger and food scarcity in many parts of the country. Research shows that in regions where the PDS is efficiently implemented, the prevalence of hunger and undernutrition has declined, highlighting the system's importance as a safety net for millions of poor households. By improving access to affordable food, the PDS supports basic sustenance, which is a critical step toward achieving the broader target of zero hunger under SDG-2.

However, while the PDS has been successful in addressing caloric needs and food availability, its impact on overall nutritional outcomes is limited. The system primarily distributes staple cereals like rice and wheat, with little emphasis on nutritional diversity such as pulses, vegetables, and fruits, which are essential for a balanced diet. As a result, many beneficiaries continue to suffer from nutritional deficiencies despite having access to sufficient calories. Secondary data reveals that reliance on the PDS alone is insufficient to meet the Recommended Dietary Allowances (RDA) for key nutrients, leading to issues such as anemia, stunting, and other forms of malnutrition. To fully realize the objectives of SDG-2, there is a growing consensus that the PDS must evolve to include a wider variety of nutritious food items and complement other nutrition-focused programs to improve the health and well-being of vulnerable populations.

Challenges in PDS Implementation

One of the most persistent challenges faced by the Public Distribution System (PDS) is the issue of leakages and diversion of food grains. Despite various reforms aimed at improving transparency and efficiency, studies estimate that a significant portion of the food grains allocated under the PDS never reaches the intended beneficiaries. Leakages occur due to pilferage at multiple points—during procurement, storage, transportation, and even at Fair Price Shops. Additionally, some grains get damaged or lost due to poor handling and storage conditions. These leakages not only reduce the effectiveness of the system but also undermine public trust, as subsidized food grains often find their way into the open market, benefiting middlemen and ineligible consumers rather than the poor.

Another major hurdle in the effective functioning of the PDS is the problem of targeting errors. The system relies heavily on accurately identifying eligible beneficiaries to ensure that subsidies reach those who need them the most. However, inaccuracies in beneficiary lists have led to both exclusion and inclusion errors. Exclusion errors occur when deserving households, often the poorest and most vulnerable, are left out due to outdated or incomplete data, lack of documentation, or administrative inefficiencies. Conversely, inclusion errors happen when non-eligible families receive benefits, straining the system's resources and reducing the availability of food grains for the genuinely needy. These targeting errors reduce the overall impact of the PDS on food security and raise concerns about equity and fairness.

Infrastructure constraints further complicate the delivery of food security through the PDS. Many storage facilities across India are inadequate, leading to substantial post-harvest losses due to spoilage, pests, and poor maintenance. This not only wastes valuable food grains but also increases the cost of procurement and distribution. Additionally, weak transportation networks, especially in remote and rural areas, delay the timely delivery of grains to Fair Price Shops, affecting the regularity and reliability of food supply to beneficiaries. These infrastructure challenges limit the capacity of the PDS to function smoothly and highlight the need for greater investment in cold storage, warehousing, and transport logistics to strengthen the system's effectiveness.

Reforms and Innovations in PDS

In recent years, technological interventions have played a crucial role in improving the efficiency and transparency of the Public Distribution System (PDS). One of the most significant innovations has been the integration of Aadhaar, India's biometric identification system, with PDS databases. This linkage helps in authenticating beneficiaries, minimizing duplication, and preventing fraudulent claims, thereby ensuring that subsidies reach the rightful recipients. Additionally, the computerization of Fair Price Shops (FPS) through the deployment of Point of Sale (POS) machines has increased transparency in transactions. These machines record real-time data on the distribution of food grains, reduce errors, and enable better monitoring by authorities, which in turn strengthens accountability at the grassroots level.

Alongside technological upgrades, several key policy initiatives have been introduced to make the PDS more inclusive and user-friendly. The One Nation One Ration Card (ONORC) scheme stands out as a transformative reform that allows beneficiaries to access their subsidized food grains from any FPS across India, significantly benefiting migrant workers and those who frequently move between states. This portability ensures uninterrupted access to food security benefits, regardless of location. Furthermore, some states have experimented with Direct Benefit Transfer (DBT), where cash subsidies are directly transferred to beneficiaries' bank accounts as an alternative to the traditional in-kind grain distribution. This approach aims to reduce leakages, empower beneficiaries with more choice, and streamline the delivery process. Together, these technological and policy innovations are reshaping the PDS to better meet the challenges of a rapidly changing social and economic landscape.

Findings and Conclusion

The above analysis of this paper clearly shows that the Public Distribution System (PDS) plays a crucial role in advancing the goals of Sustainable Development Goal 2 (SDG-2) by ensuring food availability, accessibility, affordability, and stability for millions of vulnerable households across India. The PDS's large-scale network effectively provides subsidized staples like rice and wheat to low-income families, which has contributed significantly to reducing hunger and improving basic food security. Studies indicate that households benefiting from the PDS report better food security outcomes compared to those outside the system, demonstrating its importance as a social safety net. Furthermore, recent reforms such as Aadhaar integration, computerization of ration shops, and the One Nation One Ration Card scheme have enhanced the system's transparency and reach, especially aiding migrant workers and improving accountability.

However, despite its strengths, the PDS faces substantial challenges that limit its overall effectiveness in fully achieving SDG-2. Persistent issues like leakage, diversion, and inaccurate targeting dilute the system's impact, with a significant proportion of allocated food grains failing to reach the intended beneficiaries. Additionally, while the PDS addresses caloric needs effectively, it falls short in providing nutritional diversity, as it primarily distributes cereals without adequately incorporating pulses, vegetables, or fortified foods needed to combat malnutrition. Infrastructure deficiencies, such as inadequate storage and poor transportation, further hamper efficient distribution. To meet the ambitious zero hunger targets by 2030, the PDS must continue evolving through expanded food basket diversification, improved beneficiary identification, stronger infrastructure, and innovative policy reforms that integrate nutritional goals alongside food security. Strengthening the PDS in these ways is essential to ensuring sustainable, equitable, and comprehensive food and nutrition security for all sections of Indian society.

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21.

SCHOOL DROPOUT AND CHILD MARRIAGE: A DUAL CHALLENGE TO SUSTAINABLE DEVELOPMENT GOAL

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Abstract

This study explores the strong two-way link between early marriage and school dropout among Indian adolescent girls, highlighting how both challenges hinder progress toward SDGs 4 (quality education) and 5 (gender equality). Using data from NFHS-5, UDISE+, UNICEF, and others, it finds that dropping out of school raises the risk of early marriage, and early marriage, in turn, drives school dropout. With 23.3% of women aged 20-24 married before 18 and a 14.1% secondary school dropout rate nationally—higher among marginalized groups—key drivers include parental illiteracy, poverty, patriarchal norms, infrastructural gaps, and COVID-19 disruptions. Although government initiatives like conditional cash transfers, community mobilization, gender-responsive policies and infrastructure improvements exist, enforcement of legal protections like the Prohibition of Child Marriage Act remains weak. Regional disparities are notable, especially in Bihar, West Bengal, Assam, and Tripura. The study calls for multi-sectoral collaboration, context-specific interventions, stronger legal enforcement, advanced data systems, and girl empowerment through education and life skills to break cycles of poverty and gender inequality and achieve sustainable development goals.

Keywords: SDG, NFHS, UDISE+, Early Marriage, School Dropout

Introduction

Quality education and gender equality stand at the bedrock of sustainable development, as recognized by the international organisations communities through the adoption of Sustainable Development Goals (SDGs) 4 and 5. SDG 4 calls for "promoting inclusive and equitable quality education and lifelong learning opportunities for all", while SDG 5 aims to "achieve gender equality and empower all women and girls". In the Indian context, these goals are deeply interconnected: continuation of girls' education is a precondition and a consequence of progress towards gender equality, and vice versa. The incidence of school dropout and early marriage, especially among adolescent girls, symbolize persistent obstacles to realizing these global aspirations (UN Women, 2023 and UNDP, 2023).

India's tenacious high rates of school dropout and child marriage represent "dual SDG challenges" that undermine the potential of millions of adolescent girls and threaten to halt progress towards both educational and gender-focused development goals. Extensive empirical and policy literature, including reports from the United Nations Children's Fund (UNICEF) and the United Nations Development Programme (UNDP), demonstrates that the intersection of early educational imbalances and child marriage is not accidental but driven by a complex matrix of socio-economic, cultural, demographic and institutional factors.

Dropouts Ratio among Adolescent Girls in India

National and state data highlight a critical period of vulnerability for adolescent girls in India, particularly during the transition from primary to secondary education. UDISE+ (2023–24) reports a national secondary school dropout rate of 14.1% for girls, with inter-state variation ranging from 1.3% in Bihar to over 26% in Nagaland. Dropout rates rise sharply from the primary level (1.9%) to secondary education, with states such as Odisha, Rajasthan, Uttar Pradesh, Madhya Pradesh, and Bihar showing both high dropout and declining female enrollment. NFHS-5 (2019–21) indicates that 23.3% of women aged 20–24 was married before 18 and UNICEF data show that 85% of girls aged 15–17 who are married or in union are out of school, compared with 78% of never-married peers. These findings underscore the strong link between early marriage and educational disengagement, highlighting the need for targeted interventions during adolescence to reduce dropout and empower girls.

Early Marriage among Adolescent Girls in India

Adolescent girls in India face a critical period of vulnerability during the transition from primary to secondary education, where school dropout and early marriage are strongly interlinked. UDISE+ (2023–24) reports a national secondary school dropout rate of 14.1% for girls, with inter-state variation from 1.3% in Bihar to over 26% in Nagaland, while primary-level dropout remains low at 1.9%. NFHS-5 (2019–21) indicates that 23.3% of women aged 20–24 were married before 18, with the highest risks among rural, poor, marginalized caste or tribal girls, and those with little or no education. UNICEF (2023) data further show that nearly 50% of girls with no education marry early, compared with just 3% with higher education, and that the poorest are five times more likely to marry young than the richest. These intersecting disadvantages—gender, poverty, rural residence, and limited education—highlight adolescence as a pivotal stage for intervention. Integrated strategies, including conditional cash transfers, legal enforcement of the Prohibition of Child Marriage Act, life skills education, mentorship, and community engagement, are critical to delay marriage, retain girls in school, and break intergenerational cycles of deprivation, ultimately advancing gender equality and sustainable development in India.

Table1: Educational Attainment and Child Marriage

Education Attainment	Married Before Age 18 (%)
No Education	Approximately 50%
Primary Education	33%
Secondary Education	17% (rural), 15% (urban)
Higher Education	3%

Source: NFHS-5, UNICEF India 2023

Socio-Economic and Demographic Determinants and School Dropout and Early Marriage

School dropout and early marriage among adolescent girls in India are closely linked to poverty, caste, rural residence, and parental education, with girls from marginalized and low-income households facing the highest risks. NFHS-5 shows that women with no education are 15 times more likely to marry before 18, while UNICEF and UDISE+ data reveal that these risks cluster geographically, creating hotspots of vulnerability. Social norms, weak law enforcement, and limited opportunities for young women reinforce these patterns, perpetuating cycles of disadvantage. Integrated interventions—combining educational retention, legal enforcement, financial support, life skills training, and community engagement—are essential to delay marriage, retain girls in school, and advance gender equality and sustainable development in India.

Literature Review

Studies highlight a strong link between child marriage and school dropout among adolescent girls in South Asia. In Nepal, married girls are 10 times more likely to leave school than unmarried peers, with dropout risk peaking between 7th and 10th grades; risk factors include low household head education, disadvantaged caste, and Kirat religion, prompting calls for school interventions from grade 5 and delaying marriage to improve education outcomes (Sekine & Hodgkin, 2017). Across Bangladesh, India, Nepal, and Pakistan, secondary education significantly protects against child marriage, especially under age 16, while primary education alone is generally less effective; India shows the strongest consistent protective effects (Raj et al., 2014). A review notes early marriage and pregnancy contribute to dropout but causal links are complex and context-specific, with limited South Asian data (Birchall, 2018). In Bihar, early marriage, school dropout, and childbearing correlate with poorer mental health in young women, underscoring the importance of continued education, delayed marriage, and empowerment (Yadav, 2022). A meta-analysis in India identifies 34 risk factors for dropout, emphasizing familial and individual characteristics, important for targeted policies (Venkatesan, 2024). Community-based interventions like Youth Information Centres in Indian states have effectively delayed marriage and pregnancy while improving school retention, showing promise for replication (Mehra et al., 2018).

In India, early school dropout and marriage before the legal age persist as major socio-economic and cultural challenges impeding Sustainable Development Goals (SDG) 3 (health), 4 (education), and 5 (gender equality), especially the elimination of child marriage (UNICEF, 2023). Despite government efforts over the last decade, 23.3% of women aged 20-24 were married before age 18, with high rates in West Bengal, Bihar, and Tripura (NFHS 5, 2021; UNICEF, 2023). Concurrently, 12.3% of adolescent girls drop out during secondary school (Classes 9-10) (UDISE+ 2021–22), reflecting intertwined challenges that hinder India's social and economic development.

Research Design

This study uses cross-sectional and observational research techniques based on high quality nationally and internationally recognised secondary data sources such as; National Family Health Surveys (NFHS), Unified District Information System for Education Plus (UDISE+), UNICEF, UNDP, and Peer - Reviewed Research Publications. The cross-sectional analysis allows us to explore the degree of association between child marriage and school dropout rate among adolescent girls in India during the NFHS-5 cycle. The study adopts a quantitative research design to study the elucidating trend and correlation analysis using MS Excel software.

RESULT AND DISCUSSION

Marriage Trend in India

The given table shows a significant decline at the early age marriage of both adolescent men and women from NFHS-3 to NFHS-5. The percentage of women aged 20-24 years who were married before the age of 18 significantly declined from 47.4 percent in NFHS-3 to 23.3 percent in NFHS-5, showing progressive improvements in eradicating child marriage. Similarly, the percentage of men aged 25-29 who were married before the legal age of marriage declined from 20.3 percent in 2015-16 to 17.7 percent in 2019-21. The median age of women aged 20-49 at first marriage also shows a sharp increase from 17.2 percent in 2005-06 to 19.2 percent in 2019-21.

Table 2: Trends in Child and Early Age Marriage in India

Indicator	**NFHS-3**	**NFHS-4**	**NFHS-5**
Women aged 20–24 married before age 18 (%)	47.4	26.8	23.3
Men aged 25–29 married before age 21 (%)	—	20.3	17.7
Median age at first marriage – Women aged 20–49	17.2	n/a	19.2

Source: NFHS-3,4, and 5

The above findings underscore a positive trend towards achieving sustainable development goals particularly SDG-5.3 (elimination of child, early, and forced marriage) by 2023. This progress is also contributing to achieving SDG -3, SDG-4, and SDG 5.3 because delayed marriage is significantly related to good and improved health, quality education, and socio-economic participation of women as well as men.

Prevalence of Child Marriage (Girls) in India

The map from Mudgil & Rao (2023) reveals significant regional disparities in the prevalence of child marriage among girls in India, with marked concentrations of high rates in several eastern and central districts, while lower prevalence is observed in northern, western, and some southern constituencies. Parliamentary constituencies in West Bengal, Bihar, Tripura, and Assam exhibit child marriage rates above 40%, classifying them among the worst-affected regions nationwide. In contrast, areas in the north and selected pockets in the south and west show much lower rates—ranging from below 8% up to about 16%. These spatial patterns align closely with broader socioeconomic inequalities, illustrating the interplay of marginalization, poverty, and educational gaps in sustaining the practice of child marriage. This mapping underscores the urgent necessity for regionally tailored interventions and persistent monitoring to eliminate child marriage and advance gender equity.

Table: 3 Prevalence of Child Marriage in India

Percentile	Range (%)	Geographic Pattern
10th	2.7 - 7.7	Predominantly north, some south/west pockets
20th	7.8 - 10.5	Northern states, isolated eastern regions
30th	10.5 - 12.7	North-central, western stretch
40th	12.7 - 15.7	Central transitional patches
50th	15.8 - 18.8	Spread across mid-regions
60th	18.9 - 22.7	Rising risk in parts of south/west and central
70th	22.7 - 26.8	Western, central, emerging eastern patches
80th	26.9 - 30.9	Central and some southern clusters
90th	31.0 - 40.5	Dense clusters in eastern states
100th	41.0 - 60.8	Hotspots: West Bengal, Bihar, Tripura, Assam

Source: Mudgil, S., & Rao, S. R. (2023), A data story on female child marriage in India.

Change in Prevalence of Girl child marriage from NFHS-4 to NFHS-5

The study of Mudgil & Rao (2023) visualizes the change in girl child marriage prevalence across Indian parliamentary constituencies (PCs) from NFHS-4 (2015-16) to NFHS-5 (2019-21). Nationally, rates declined from 26.8% to 23.3%, with 77% of PCs recording improvements. However, about 23% of PCs saw an increase, with some areas worsening by more than 10 percentage points. Notably, PCs such as Salem (Tamil Nadu), Parbhani (Maharashtra), and Jhansi (Uttar Pradesh) experienced significant regression despite better trends among their neighbors, highlighting localized setbacks. These variances stress the necessity for focused research and tailored interventions to address the underlying causes in the most-affected PCs.

Table: 4 Change in Prevalence of Girl child marriage from NFHS-4 to NFHS-5

Change Category	Min-Max Change (%)	Number of PCs	Description
Highest Improvement	-21.8 to -4.6	210	Marked decrease in child marriage prevalence
Improvement	-4.6 to 0	210	Moderate decrease
Worsened	0 to 2	62	Slight increase
Extremely Worsened	2 to 18.3	61	Significant increase, with some PCs exceeding 10 percentage points

Source: Mudgil, S., & Rao, S. R. (2023), A data story on female child marriage in India.

Rural-Urban Comparison of Early Age Marriage (NFHS-5, 2019–21)

The NFHS-5 data shows significant disparity in rural- urban early marriage. 27 percent women aged 20-24 in rural areas were married before the legal age, compared to only 14.7 percent in urban areas, highlighting the significant persistence of child marriage in rural areas. Similarly early age marriage among rural and urban men shows parallel divide.

Table: 5 Urban Comparison

Area	Women Married <18 (%)	Men Married <21 (%)
Rural	27.0	21.1
Urban	14.7	11.3

Source: NFHS- 5

Above result indicates that despite significant improvements in increasing age of marriage, rural communities still face huge socio-economic and cultural barriers such as poverty, limited access to quality education and lack of health and medical awareness. In the contrary urban communities benefit from better quality education and employment opportunities, quality healthcare services and awareness, and better enforcement of legal framework. These rural- urban disparities underscore the needs for targeted policy intervention such as expanding access to quality education in rural areas particularly physical education, improving awareness regarding side-effect of early and child marriage, and ensuring consistent delivery of quality education.

Status of Dropout Rates and School Attendance in India

School attendance and dropout ratio is the key indicators for effectiveness of educational achievements across the world. In last 10 years primary and upper primary dropout rate experiences has declined, but secondary dropout rate is still 16.4 percent, in compered to 7.8 percent in primary and 8.1 percent in upper primary education (UDISE+ 2023). The UDISE+ 2023-24 shows modest improvement in dropout ratio at school level. Primary level dropout ratio surged to 7.8 percent; upper primary education surged to 5.2 percent and secondary level dropout improved to 14.1 percent in 2023-24. But regional disparity is still centre of concern. For example, Karnataka registered highest secondary level dropout rate of 22.09 percent, followed by Bihar and Assam. On contrary Kerala recorded only 3.4 percent dropout rate, while West Bengal became the first state to achieve zero female dropout rates in primary education and significantly reduces the secondary and higher secondary dropout rate to 2.9 percent and 3.2 percent respectively.

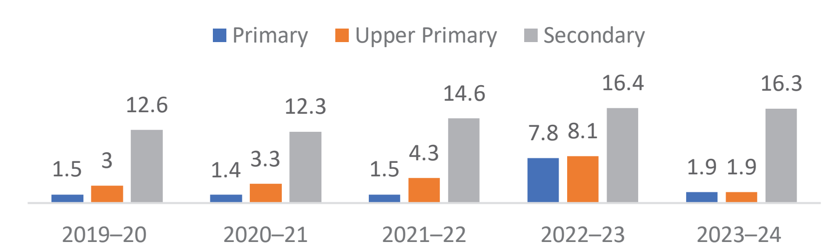
Table: 6 School Attendance and Dropout Rates (NFHS, UDISE+)

Indicator	Urban (%)	Rural (%)	Total (%)
Female population age 6+ ever attended school	82.5	66.8	71.8
Women with 10 or more years of schooling (15–49)	56.3	33.7	41.0
Women who are literate (15–49)	83.0	65.9	71.5
Girls (15–19) currently attending school	–	–	48.8
Girls (15–19) not currently attending school	–	–	51.2

Source: NFHS- 5 and UDISE + 2023-24

The above table shows the urban rural disparities in school attendance among adolescent girls. In India 82.5 percent urban girls aged 6+ years have ever attended schools but in rural areas this proportion drops to 66.8 percent. This gap becomes more wider when we examine the women with 10 or more years of schooling (15-49 years), 56.3 percent urban women and girls reported 10 or more years of school attendance but in rural areas only 33.7 percent. As per UDISE+ 2023-24 data only 48.8 percent girls (15-19 years) are currently in school, and 51.2 percent are dropout. This huge dropout ratio significantly affects the pace of human as well as fiscal capital formation and perpetuates cyclical disadvantage in rural areas that already faces various socio-economic and cultural barriers. Dropout ratio and early marriage among adolescent girls reveal how structural inequalities in access to and retention in education disproportionately affect rural and adolescent girls, reinforcing vulnerabilities that impede progress towards SDG 4 (quality education) and indirectly perpetuating risks associated with SDG 3 (good health and well-being).

Figure:1 National Dropout Rate Trends (2019–24)

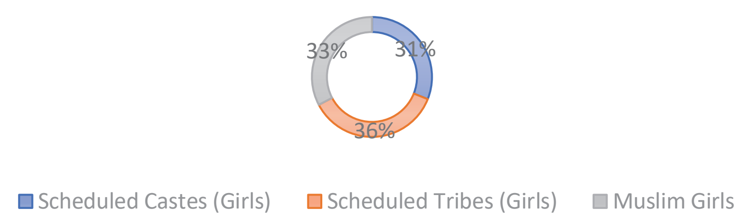


Source: UDISE+ 2023-24

Between 2019-20 and 2023-24, UDISE data shows that dropout rates remained relatively low at the primary and upper primary levels, with temporary spikes in 2022-23 due to post-pandemic disruptions, but declined thereafter. However, the secondary level continues to face high dropout rates (16.3% in 2023-24), making adolescence a tipping point. This reflects the impact of socio-economic pressures, gender norms and early marriage, which directly links to challenges in achieving SDG 4 and SDG 3.

Social Group Disparities

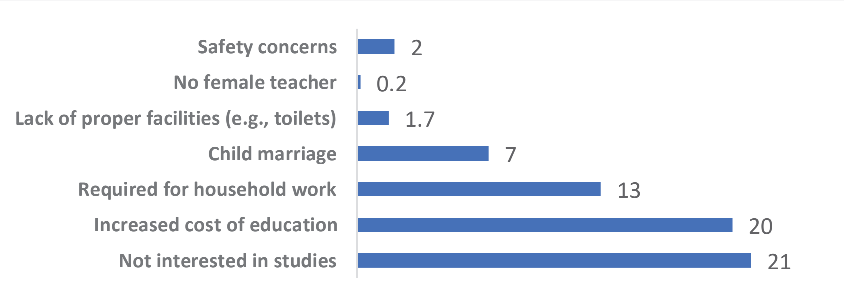
Figure: 2 Dropout Rate (Secondary Education (%)



Source: UDISE + 2023-24

The above figures reflect social group disparities in secondary school dropout among girls, with the highest rates among ST (26.3%), Muslim (23.7%) and SC (22.5%) girls. These disparities arise from poverty, marginalisation and gender barriers such as early marriage, child labour and limited school access in rural and tribal areas. Such inequalities hinder progress towards SDG 4 (quality education) and SDG 5 (gender equality), underscoring the need for targeted support such as scholarships, safe transport and community-based interventions.

Figure: 3 Reasons for Dropout among Adolescent Girls



Source: NFHS, NCPCR, UNICEF

Dropout rates differ significantly between girls and boys, with girls being disproportionately affected by socio-economic and cultural barriers. Lack of interest in studying is the most common reason, while child marriage accounts for 7% of female dropouts. Institutional barriers such as inadequate sanitation and safety concerns also affect girls. These findings highlight the link between dropout and SDGs 4 and 5.

Current Status of State Wise School Dropout and Child Marriage in India

India's state-wise disparities in girls' secondary education and child marriage are a significant issue. The child marriage rate is 23.3%, with West Bengal, Bihar and Tripura reporting rates over 40%. Kerala, Himachal Pradesh, Goa and Delhi have maintained rates below 10%. Similarly, several states have high female secondary school dropout rates, with Assam, Karnataka and Bihar reporting rates over 20%. This highlights the link between education and early marital practices, emphasising the need for state-specific strategies to interrupt this cycle. This is in line with India's commitments under SDG 4 and SDG 5.

Table: 7 Current Status of State Wise School Dropout and Child Marriage in India

State/UT	Girls' Secondary Dropout Rate (%) (UDISE+ 21–22)	Women 20–24 Married <18 (%) (NFHS-5)	State Wise Correlation Insight
Andhra Pradesh	15	29.3	0.520007
Arunachal Pradesh	12.3	12.1	0.510262
Assam	20.7	31.8	0.525077
Bihar	21.4	40.8	0.491166
Goa	5.5	11	0.402158
Gujarat	15.9	24.9	0.385586
Haryana	4.9	19.4	0.37056

Himachal Pradesh	0.9	11.3	0.376646
Jharkhand	8.9	35.6	0.339829
Karnataka	13	23.1	0.393119
Kerala	4.1	6.3	0.386731
Madhya Pradesh	9.7	32.4	0.337062
Maharashtra	10.6	25.6	0.378535
Manipur	1.2	16.5	0.389109
Meghalaya	20.4	20.1	0.400633
Mizoram	10.8	16.1	0.409052
Nagaland	16.2	17.4	0.409816
Odisha	25.2	21.3	0.429451
Punjab	16	8.1	0.513313
Rajasthan	7.5	25.4	0.791144
Sikkim	9.5	9.5	0.825504
Tamil Nadu	2.5	12.8	0.897271
Telangana	12.9	23.5	0.910915
Tripura	8.2	21.5	0.931512
Uttar Pradesh	10	22.6	0.935425
Uttarakhand	4.6	17.4	0.93437
West Bengal	17.7	41.6	0.982814
Delhi	3.7	7.8	-1
Jammu & Kashmir	6.3	7.4	-

Sources: UDISE+ 2021–22, NFHS-5 (2019–21)

The data show a clear positive relationship between girls' secondary school dropout rates and child marriage in most Indian states. Strong correlations (above 0.9) are observed in states such as West Bengal (0.98), Uttar Pradesh (0.93), Tripura (0.93), Telangana (0.91), Tamil Nadu (0.89) and Uttarakhand (0.93). States such as Rajasthan, Assam, Andhra Pradesh, Sikkim and Punjab show moderate associations (around 0.5-0.8), suggesting a noticeable but slightly weaker relationship. Meanwhile, states such as Kerala, Himachal Pradesh, Jharkhand and Madhya Pradesh show weak correlations (below 0.4), meaning that dropouts and child marriage are less strongly linked, possibly due to stronger education systems or social reforms. Some entries such as Delhi and Jammu and Kashmir have invalid or missing data. Overall, the data support the idea that reducing school dropouts could be an important strategy for reducing child marriage rates, especially in states with high correlations.

Findings and Policy Recommendations

In India, school dropout and child marriage remain persistent challenges, especially in states like Bihar, Assam, Odisha, and West Bengal where over 20% of girls drop out during secondary school. Targeted measures such as conditional cash transfers, free uniforms, textbooks, and expanded hostel facilities have proven effective in improving retention. Early marriage affects more than 40% of women aged 20–24 in Bihar, West Bengal, and Tripura, highlighting the urgent need to strengthen enforcement of the Prohibition of Child Marriage Act (PCMA) through Child Marriage Prohibition Officers (CMPOs), legal accountability, and cash transfer schemes. Research confirms a two-way link between dropout and child marriage, emphasizing integration of life skills, mentorship, and career guidance in schools to empower girls. Marginalized groups—including Scheduled Castes, Scheduled Tribes, Other Backward Classes, and rural poor—face disproportionate risks, calling for intersectional data and tailored inclusion strategies. Weak law enforcement and low conviction rates under PCMA require fast-track courts, digital monitoring, and robust CMPO networks. Deep-rooted cultural barriers, such as patriarchal norms and social pressures, demand community engagement, awareness campaigns, and youth platforms to challenge harmful practices. Addressing dropout and early marriage thus requires coordinated education, legal, cultural, and social reforms.

Table: 8 Summary of Findings and Summary

Challenge/Gap	Evidence/Stats	Effective Policy/Intervention
High dropout in secondary (≥ 20%)	Bihar, Assam, Odisha, W. Bengal	Cash transfers, free uniforms, hostels
Early marriage (≥ 40%)	Bihar, West Bengal, Tripura	CMPO enforcement, legal action, CCTs

(Before the legal age of 18)		
Bidirectional link between dropout and marriage	Nationally established	Life skills education, career guidance
Marginalised community risk	SC/ST/OBC girls, rural poor	Intersectional data, targeted inclusion
Poor law enforcement	Low convictions under PCMA	Fast-track courts, CMPOs, real-time portals
Cultural barriers	Rural/SC/ST prevalence, patriarchal norms	Community engagement, adolescent voices

Source: Author's Estimations

Conclusion

Early marriage and school dropout rates among adolescent girls in India continue to limit their potential and impede the country's progress toward gender equality (SDG 5) and high-quality education (SDG 4); while southern and western states have higher levels of education, women's empowerment and social programs, regional variations demonstrate how poverty, social exclusion, and gender bias concentrate risk in eastern, northeastern and central and northern India. According to research integrated multi-sectoral programs that include financial incentives, mentorship, life skills education, legal enforcement and community involvement are critical for retaining girls in school and delaying marriage. To break the cycle of disadvantage, tailored interventions and participation platforms must address long-standing cultural and societal impediments. Encouraging girls' health, education and economic outcomes, as well as strengthening social resilience, makes this a key priority for India's 2030 goals of gender equity, poverty reduction and sustainability.

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22.

THE ROLE OF AGRICULTURAL PRODUCTIVITY AND SUSTAINABILITY IN THE ACHIEVEMENT OF ZERO HUNGER GOAL

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Abstract

This research paper explores how improving both agricultural productivity and environmental sustainability can help India achieve Sustainable Development Goal 2 (Zero Hunger). While India has made strong progress in crop production and economic growth, challenges like undernutrition, unequal food access, and environmental damage remain. Using secondary data from sources such as FAO, NITI Aayog, the Ministry of Agriculture, and NFHS surveys, the study looks at national and state-level trends in food security. It also assesses the role of key government schemes like PM-KISAN, PM-AASHA, the National Mission for Sustainable Agriculture (NMSA), and the Public Distribution System (PDS) in improving food and nutrition for the poor. The findings show that even though food production and farm income have increased, many states—especially those dependent on rainfed farming—still face serious nutrition problems. The paper calls for better coordination of policies that support both higher yields and environmental care, through climate-friendly farming, better food distribution, and strong support for small farmers. The study ends by recommending practical steps like organic farming, use of technology, data-

driven planning, and stronger governance to help India reach Zero Hunger by 2030.

Keywords: Zero Hunger, SDG 2, Agricultural Productivity, Food Security, Sustainability

Introduction

India, with a population of nearly 1.4 billion, stands at a crucial crossroads in its fight against hunger and malnutrition. While the country has witnessed remarkable growth in agricultural output and economic development over the past decades, these gains have not fully translated into improved nutritional outcomes or equitable food access. According to recent data from the National Family Health Survey (NFHS-5) and the Global Hunger Index (2023), a significant portion of the population, especially in rural and rainfed regions, continues to suffer from undernourishment, child stunting, and food insecurity. This situation underscores the urgent need for a more integrated and inclusive approach to food systems. Sustainable Development Goal 2 (Zero Hunger) aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture by 2030. However, achieving this goal in India requires addressing not only the supply of food but also the ecological and social factors that influence its accessibility and sustainability. Agricultural productivity remains a key driver in this process, but it must be balanced with environmental sustainability, equitable distribution, and climate resilience. The challenge is further complicated by the diversity of India's agro-climatic zones, socio-economic inequalities, and fragmented governance structures.

This paper explores the interconnected role of agricultural productivity and sustainability in achieving Zero Hunger in India. It assesses the effectiveness of major government programs such as PM-KISAN, PM-AASHA, the Public Distribution System (PDS), and the National Mission for Sustainable Agriculture (NMSA) in enhancing food security and improving rural livelihoods. By analyzing state-level disparities, ecological risks, and policy gaps, the study highlights the importance of inclusive, climate-smart, and data-driven strategies. The ultimate goal is to offer a roadmap for building a resilient, equitable, and sustainable agri-food system capable of ensuring food and nutrition security for all Indians by 2030.

Literature Review and Conceptual Framework

Food security has evolved as a multidimensional concept involving food availability, access, utilization, and stability (FAO, 2008). Studies such as those by von Braun et al. (2014) and Burchi et al. (2011) emphasize the integration of nutrition-sensitive agriculture and sustainable intensification. De Janvry and Sadoulet (2020) emphasize agricultural growth as a central pathway to hunger reduction, yet highlight persistent barriers such as market failures and institutional weaknesses. Pingali (2015) introduced the concept of a 'quiet revolution' in agriculture focusing on supply chains and non-farm linkages. Suryanarayana et al. (2017) and Meenakshi (2016) have documented how improvements in calorie availability alone are insufficient unless coupled with improvements in sanitation and maternal care. The National Nutrition Strategy (NITI Aayog, 2017) emphasizes convergence across sectors including agriculture, health, and sanitation.

Objective of the Study

1. To evaluate the role of agricultural productivity and sustainability in achieving Sustainable Development Goal 2 (Zero Hunger) in India, with a focus on regional disparities and policy effectiveness.
2. To assess the impact of key government schemes and climate-resilient agricultural practices on food security and nutritional outcomes across diverse Indian states.

Methodology

This study utilizes a descriptive-analytical methodology, primarily based on secondary data sources, to explore the relationship between agricultural development and nutritional outcomes in India. The analysis draws upon a wide range of datasets, including agricultural statistics from the Ministry of Agriculture (MoA) and the Food and Agriculture Organization (FAO) covering the period from 2010 to 2023, providing a comprehensive view of trends in crop production and agricultural growth. For nutritional indicators, the study refers to data from the National Family Health Surveys (NFHS-4 and NFHS-5), which offer insights into undernourishment, child stunting, and other key health parameters. The research also examines state-level agricultural dashboards published by NITI Aayog, which serve as valuable tools for monitoring real-time progress across different regions.

The paper reviews policy documents, government scheme reports, and implementation data from flagship programs such as PM-KISAN, PM-

AASHA, the National Mission for Sustainable Agriculture (NMSA), and the Public Distribution System (PDS). These sources help evaluate the effectiveness of institutional support mechanisms in driving agricultural growth and food security.

Furthermore, the study incorporates insights from international literature on food security frameworks and agricultural sustainability to contextualize India's performance globally. A comparative analysis across states is conducted to identify spatial heterogeneity, allowing for the recognition of regional disparities and the documentation of emerging best practices that can inform policy design and replication elsewhere.

National Progress Toward Zero Hunger

India has made remarkable strides in food production, with cereal output reaching 330 million tonnes in 2023 (MoA, 2023), reflecting the success of agricultural reforms, improved irrigation, and increased use of technology. Despite this growth, nutritional outcomes have improved at a slower pace. According to the Global Hunger Index 2023, India was ranked 111th out of 125 countries, highlighting a persistent gap between economic and agricultural advancement and improvements in human development indicators such as nutrition and health. the Government of India has implemented several flagship initiatives aimed at improving food access and reducing malnutrition. The PM-KISAN scheme has provided direct income support, disbursing over INR 2 lakh crore to nearly 110 million farmers, thereby strengthening smallholder incomes and food security. The PM-AASHA programme has expanded the coverage of Minimum Support Price (MSP) procurement, ensuring price support for farmers producing essential crops. The Public Distribution System (PDS) and the National Food Security Act (NFSA) together offer subsidized food grains to approximately 800 million beneficiaries, creating a safety net for vulnerable populations.

In addition, the POSHAN Abhiyaan (National Nutrition Mission) serves as a convergent strategy for tackling malnutrition through multi-sectoral interventions. The NFSA further strengthens food security by providing legal entitlements to subsidized food grains, ensuring that the right to food is protected for a large segment of the population. Together, these initiatives represent a comprehensive effort to advance toward the Zero Hunger goal (SDG 2), though the data suggests that deeper integration of agricultural policy with nutrition and health strategies is still needed.

Table 1: Key Indicators of Food Security in India (2015 vs. 2023)

Indicator	2015	2023
Cereal Production (million tonnes)	252	330
% Undernourished	15%	11.6%
Children under 5 stunted (%)	38.4%	35.5%
Agricultural GDP growth	2.5%	3.4%

Source: DoA&FW

Between 2015 and 2023, India saw significant progress in agriculture and nutrition. Cereal production rose from 252 to 330 million tonnes, showing improved food availability. The percentage of undernourished people declined from 15% to 11.6%, indicating better access to food. Child stunting among children under 5 dropped slightly from 38.4% to 35.5%, reflecting ongoing challenges in nutrition and health. Agricultural GDP growth increased from 2.5% to 3.4%, showing modest economic progress in the sector. While gains are evident, more efforts are needed to address child malnutrition and strengthen rural livelihoods.

State-Level Insights

Agricultural performance and nutritional outcomes across Indian states reveal stark regional disparities, influenced by climatic conditions, resource availability, and policy implementation. In Punjab and Haryana, agricultural productivity remains among the highest in the country, with rice and wheat yields averaging over 4,000 kg/ha. These gains are driven by extensive canal and groundwater irrigation and the Minimum Support Price (MSP) procurement system. For example, over 85% of cultivated land in these states is irrigated, and more than 80% of wheat and paddy produce is procured by government agencies. However, this success has come at a cost—Central Ground Water Board (2022) reports indicate that over 75% of blocks in Punjab are now in the over-exploited category, highlighting the alarming depletion of aquifers due to water-intensive monocultures.

On the other hand, states like Bihar, Jharkhand, and Odisha lag behind with low productivity and high undernutrition rates. In Jharkhand, cereal yields are below 2,000 kg/ha, and over 70% of agricultural land is rainfed, making farming highly vulnerable to erratic rainfall. According to NFHS-5 (2019–21), 35.5% of children under five in Jharkhand are stunted, and 39.6% are underweight, among the highest in India. These figures point to a need for improved agricultural diversification, nutrition-sensitive programs, and irrigation expansion in these eastern states.

Maharashtra, Karnataka, and Rajasthan face frequent droughts and water stress, which hamper crop yields and rural livelihoods. Rajasthan, for instance, receives an average annual rainfall of only 531 mm, one of the lowest in the country. In Maharashtra, recurrent droughts in Marathwada and Vidarbha regions have been linked to rising farmer distress. Although these states have introduced schemes like Jalyukt Shivar (Maharashtra) and Krishi Bhagya (Karnataka) to promote water conservation, the adoption of climate-resilient technologies such as micro-irrigation, drought-resistant seeds, and precision farming remains limited. Data from the Agricultural Census (2021) shows that less than 30% of farmers in these regions have adopted sustainable practices, underscoring the need for improved outreach and infrastructure.

In contrast, Kerala and Sikkim have emerged as models of agroecological sustainability. Sikkim, with a total cultivable area of 76,000 hectares, has achieved 100% organic certification under the Paramparagat Krishi Vikas Yojana (PKVY). This transition has not only reduced chemical input use but also enhanced soil health and market value for its crops. Kerala, though limited in land availability, promotes integrated farming systems, homestead gardens, and crop-livestock-fish integration, contributing to both nutritional security and ecological balance. According to the Kerala State Planning Board (2022), over 60% of rural households practice kitchen or terrace gardening, directly enhancing dietary diversity at the household level.

State-wise Malnutrition

State wise details of malnourished children (0-5 years) in the country for October 2022, October 2023 and October 2024 from Poshan Tracker are as follows:

State	Oct, 2022			Oct, 2023			Oct, 2024		
	Stunte d (%)	**Wa sted (%)**	**Und erwe ight (%)**	**Stunt ed (%)**	**Was ted (%)**	**Unde rweig ht (%)**	**Stunte d (%)**	**Wasted (%)**	**Under weight (%)**
Andhra Pradesh	21.2	5.3	10.5	18.2	5.4	8.7	22.6	5.3	10.8
Arunachal Pradesh	33.3	5.3	14.6	27.2	4.6	9.1	32.7	4.1	9.6
Assam	39.0	8.2	19.0	39.0	5.0	15.9	42.4	3.8	16.3
Bihar	42.9	11.0	25.8	45.0	9.0	22.7	43.8	9.2	22.9
Chhattisgarh	39.0	10.4	17.9	29.4	11.3	15.5	21.5	7.0	13.1
Goa	37.2	9.0	16.2	18.8	2.3	5.8	4.1	0.6	1.7
Gujarat	53.6	8.1	23.1	43.6	8.9	20.7	40.8	7.8	21.0
Haryana	30.1	8.5	14.0	25.9	5.7	8.9	28.2	4.1	8.7
Himachal Pradesh	26.1	4.6	10.8	21.7	2.4	7.2	18.4	1.7	6.3
Jharkhand	43.2	12.1	25.9	38.8	8.8	18.8	43.8	6.2	19.3
Karnataka	41.0	8.9	20.7	39.7	7.5	17.5	39.7	3.2	17.1
Kerala	37.2	9.5	15.3	33.1	4.8	10.1	34.4	2.3	9.5
Madhya Pradesh	52.4	9.7	33.0	40.5	8.2	23.6	46.5	6.9	26.5
Maharashtra	49.5	7.1	21.8	48.1	5.6	17.5	47.7	4.1	16.5
Manipur	17.8	2.8	7.6	16.3	1.2	7.7	7.7	0.3	2.6
Meghalaya	27.4	3.1	8.7	24.7	1.8	6.6	18.2	0.4	4.5
Mizoram	20.0	4.2	6.2	23.5	3.7	5.6	26.7	2.3	5.9
Nagaland	27.8	6.9	9.8	22.9	4.6	7.0	28.0	5.3	6.6
Odisha	30.6	5.9	14.7	34.3	4.0	14.8	29.1	2.9	12.8

Punjab	32.9	9.2	12.9	18.0	5.4	7.9	18.4	3.0	5.9
Rajasthan	37.0	11.6	20.0	35.7	7.5	16.7	36.6	5.5	17.7
Sikkim	12.2	2.8	2.7	14.1	2.8	3.1	9.2	1.5	1.7
Tamil Nadu	22.6	6.1	10.5	16.6	4.8	8.1	13.4	3.6	7.1
Telangana	29.6	5.7	14.3	30.8	4.6	13.5	32.6	5.6	16.2
Tripura	36.9	9.2	16.3	37.8	7.2	15.4	40.5	6.3	16.6
Uttar Pradesh	45.2	9.5	21.7	45.7	5.7	19.4	48.0	3.9	19.4
Uttarakhand	31.8	6.7	8.4	33.4	6.3	8.4	21.0	1.5	5.4
West Bengal	41.1	10.1	16.2	38.1	8.6	12.5	38.0	7.5	13.0
Andaman & Nicobar Islands	24.0	6.9	10.8	20.7	4.5	8.2	8.7	2.3	3.9
Dadra & Nagar Haveli - Daman & Diu	52.9	15.4	40.1	45.2	12.5	32.8	35.9	3.3	16.1
Delhi	32.8	4.5	16.5	33.6	4.8	19.1	41.9	3.0	20.6
J&K	14.5	2.5	5.6	18.1	2.5	5.1	12.1	0.7	3.0
Ladakh	27.9	5.3	8.0	15.9	1.8	3.5	11.0	0.2	2.0
Lakshadweep	100.0	0.0	75.0	39.9	11.8	19.4	46.5	11.9	25.1
Puducherry	26.0	9.3	12.0	29.0	7.9	11.6	40.2	6.8	13.0
UT-Chandigarh	36.6	4.5	18.0	34.1	0.7	12.0	26.3	1.8	11.8

Source: Ministry of women and child development

The state-wise malnutrition data from the Poshan Tracker (October 2022 to October 2024) highlights a mixed trend in India's progress toward reducing child malnutrition among children aged 0–5 years. Several states, including

Goa, Himachal Pradesh, Kerala, and Chhattisgarh, have made notable progress, showing a significant decline in stunting, wasting, and underweight prevalence. For instance, Goa reduced stunting from 37.2% in 2022 to just 4.1% in 2024. Similarly, Chhattisgarh witnessed a sharp drop in stunting from 39% to 21.5% and underweight prevalence from 17.9% to 13.1%. However, states like Bihar, Uttar Pradesh, Madhya Pradesh, and Jharkhand continue to report high levels of stunting (above 40%) and underweight children, despite marginal improvements over the years. In 2024, Uttar Pradesh recorded a stunting rate of 48% and underweight rate of 19.4%. Some northeastern and tribal regions such as Assam, Tripura, and parts of Gujarat also showed persistent or increasing levels of undernutrition. A few regions like Dadra & Nagar Haveli and Lakshadweep displayed erratic trends, with extremely high malnutrition percentages in 2022 that saw some improvement by 2024. Overall, the data indicates that while many states have benefitted from government nutrition programs and targeted schemes, child malnutrition remains a critical challenge in several economically and climatically vulnerable areas. Focused, data-driven, and region-specific strategies are essential to close the nutrition gap and achieve Sustainable Development Goal 2 by 2030.

Policy Gaps and Sustainability Challenges

Despite the presence of comprehensive agricultural and nutrition-related programs at both the central and state levels, several policy gaps and sustainability challenges continue to hinder progress toward achieving long-term food and nutritional security. One major issue is fragmentation in policy implementation. Many schemes operate in silos, with overlapping objectives and weak coordination between departments such as agriculture, food, rural development, and health. This lack of integration often results in duplication of efforts and inefficient resource use.

Another critical concern is the persistent disparity in access, especially for small and marginal farmers, who constitute over 85% of India's farming community. These farmers often struggle to access subsidies, modern technologies, credit, and insurance, limiting their ability to adopt climate-resilient or productivity-enhancing practices. While schemes like PM-KISAN and PMFBY are designed to be inclusive, barriers such as digital illiteracy, land ownership issues, and administrative delays reduce their effectiveness for the most vulnerable.

Environmental sustainability also remains a pressing issue. The over-reliance on the rice-wheat cropping system, particularly in northwestern states, has led to severe problems like soil nutrient depletion, declining groundwater tables, and increased chemical usage. This input-intensive model of agriculture is not only unsustainable but also contributes to long-term ecological damage, reducing the sector's resilience to shocks.

Moreover, climate vulnerability is an escalating threat. Irregular rainfall patterns, rising temperatures, prolonged dry spells, and frequent extreme weather events such as floods and heatwaves are increasingly disrupting agricultural production cycles across many regions. These climatic shifts not only lower yields but also affect food availability, farmer incomes, and nutrition outcomes, especially in rainfed and drought-prone areas.

Addressing these challenges requires greater policy convergence, targeted support for smallholders, and a shift toward sustainable and climate-smart agricultural practices to ensure inclusive and resilient food systems.

Recommendations and Role of Government Programs

To effectively advance towards the Zero Hunger goal while ensuring ecological sustainability and equity, it is imperative that government programs evolve to address both productivity enhancement and environmental stewardship. One of the foremost recommendations is to mainstream climate-smart agriculture across all agro-climatic regions. This involves promoting practices such as crop diversification, conservation agriculture, organic and natural farming, integrated pest management, and efficient irrigation methods like drip and sprinkler systems. The National Mission for Sustainable Agriculture (NMSA), Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), and Paramparagat Krishi Vikas Yojana (PKVY) can be revitalized and scaled up with region-specific implementation strategies to ensure these sustainable techniques are adopted by small and marginal farmers, particularly in rainfed and drought-prone areas.

Second, to address the issue of undernourishment and poor dietary diversity, especially in states with high levels of child stunting and underweight populations, the Public Distribution System (PDS) should be diversified to include nutrition-rich foods such as millets, pulses, and locally grown vegetables. This recommendation is in line with the National Food Security Act (NFSA) and government-led Millet Missions, which aim to promote climate-resilient and nutrient-dense crops. Ensuring a decentralized procurement and distribution system that supports local farmers while meeting nutritional needs of the population would also contribute to regional food sovereignty and improved diet quality.

Third, strengthening agricultural extension services is crucial. Programs like the Digital Agriculture Mission, Agri-Stack, and Agri-Clinic and Agri-Business Centre (ACABC) schemes should be expanded to include mobile-based advisory services, localized weather forecasting, market intelligence, and farm input planning. Capacity building through farmer field schools and women-centric extension models can bridge the knowledge gap and improve adoption rates of sustainable technologies. Furthermore, providing training and financial support to youth and women in agriculture can foster agri-entrepreneurship and strengthen rural economies.

Fourth, the study recommends enhancing the effectiveness of income-support and price assurance programs, especially PM-KISAN and PM-AASHA. These schemes must be made more accessible through simplified digital platforms, proper targeting of beneficiaries, and elimination of bottlenecks related to land ownership documentation. Expanding the Minimum Support Price (MSP) coverage to include a wider range of crops and increasing procurement in underperforming states can make these policies more equitable. Additionally, integrating these schemes with weather-based crop insurance like PMFBY (Pradhan Mantri Fasal Bima Yojana) would offer comprehensive risk mitigation to farmers.

Finally, the study strongly recommends building robust, real-time agricultural data systems for evidence-based policy formulation and monitoring. The use of satellite imagery, AI-driven analytics, and sensor technologies—under platforms such as the India Digital Ecosystem for Agriculture (IDEA) and ISRO's Crop Monitoring System—can help in early warning, yield forecasting, input planning, and identifying vulnerable regions. This data can be crucial for policy convergence across sectors like agriculture, nutrition, and health to ensure integrated development.

In conclusion, these recommendations aim to address the twin challenges of hunger and environmental sustainability by enhancing institutional support, promoting inclusive policies, and embedding resilience into India's agri-food systems. When effectively implemented, these government programs can play a transformative role in fulfilling the objectives of this study and guiding India toward the successful realization of Sustainable Development Goal 2.

Conclusion

India's journey toward achieving Sustainable Development Goal 2 – Zero Hunger – has seen both progress and challenges. While agricultural output has increased significantly, with cereal production rising from 252 million tonnes in 2015 to 330 million tonnes in 2023, improvements in nutrition, especially among children, have not kept pace. Government schemes like PM-KISAN, PM-AASHA, PDS, and POSHAN Abhiyaan have supported food availability and farmer incomes, but undernutrition and child stunting remain widespread in several states.The study highlights regional disparities—states like Punjab and Haryana show high productivity but face environmental concerns, while states such as Jharkhand, Bihar, and Uttar Pradesh struggle with low yields and poor nutrition indicators. Climate change, fragmented policies, and limited access to resources for small farmers further hinder progress.

To meet the Zero Hunger goal, India must focus on building sustainable, inclusive, and nutrition-sensitive food systems. This includes promoting climate-resilient farming, diversifying the PDS with nutrient-rich foods, and ensuring stronger coordination between agriculture, health, and nutrition programs.

In summary, ending hunger in India will require a balanced approach that improves productivity while safeguarding the environment and ensuring equitable access to nutritious food. With region-specific, long-term, and integrated strategies, India can move closer to achieving Zero Hunger by 2030.

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23.

EVALUATING INDIA'S POLITICAL STRATEGIES AND INSTITUTIONAL FRAMEWORKS IN STRENGTHENING MULTI-STAKEHOLDER PARTNERSHIPS FOR ACHIEVING SUSTAINABLE DEVELOPMENT GOAL- 17

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Abstract

Sustainable Development Goal 17 (SDG 17), which emphasizes partnerships as a foundation for the 2030 Agenda, highlights the need for coordinated strategies across sectors, governance levels and international platforms. This article examines India's political strategies and institutional frameworks in advancing SDG 17, emphasizing its dual role as a developing country addressing domestic challenges and a leader in South-South cooperation. Key strategies include NITI Aayog's leadership in national coordination, India's engagement through the India-UN Development Partnership Fund, and fiscal reforms such as the Goods and Services Tax (GST) and Direct Benefit Transfers (DBT), which enhance resource mobilization and policy coherence. Institutional frameworks spanning national and state structures, public–private partnerships, civil society and international actors demonstrate India's multi-stakeholder approach. Persistent challenges—such as weak

decentralization, data gaps, limited local capacity and uneven private sector engagement—continue to constrain progress. Nonetheless, best practices like Kerala's decentralized governance and digital governance innovations showcase scalable pathways for accountability and inclusion.Overall, India's experience offers valuable insights for operationalizing multi-stakeholder partnerships in large, diverse democracies, providing benchmarks for global SDG 17 implementation by 2030.

Keywords: SDG 17, Partnerships, India, Governance& Sustainable Development.

Introduction

Sustainable Development Goal 17, *"Strengthen the means of implementation and revitalize the global partnership for sustainable development,"* recognizes that achieving the 2030 Agenda requires collaboration across sectors, borders and stakeholder groups (United Nations, 2019). Unlike the preceding goals that focus on specific outcomes, SDG 17 serves as the enabling framework for realizing all other goals through cooperation, resource mobilization, technology transfer, capacity building, and policy coherence. It encompasses 19 targets across finance, technology, capacity building, trade and systemic issues, measured by 25 indicators that assess progress in creating an environment supportive of sustainable development. The framework highlights that the interconnected challenges of the SDGs cannot be resolved in isolation but demand coordinated action that draws on the complementary strengths of governments, the private sector, civil society, international organizations and local communities (Pattberg et al., 2015).

Multi-stakeholder partnerships (MSPs) have become the central mechanism for implementing SDG 17, building on earlier global governance efforts such as Agenda 21 from the 1992 Earth Summit and the Johannesburg Plan of Implementation in 2002 (The Partnering Initiative, 2023). MSPs are collaborative arrangements that bring together actors from different sectors to share risks, combine resources, and pursue common objectives through innovative and sustainable approaches. Their theoretical foundation lies in the idea that each sector contributes distinct assets: governments provide policy frameworks and legitimacy; the private sector brings innovation and market access; civil society offers local knowledge and advocacy; while international organizations contribute expertise and global networks (Stott & Murphy, 2024). Despite their promise, studies of earlier MSPs reveal challenges related to accountability and effectiveness, raising doubts about their ability to achieve the transformative change envisioned by the 2030 Agenda (Pattberg et al., 2015).

India, as the world's most populous democracy and home to one-sixth of humanity, holds a distinctive role in global SDG efforts. The country simultaneously faces its own development challenges while emerging as a leader in South-South cooperation and international development partnerships. Its approach to SDG 17 reflects a layered governance system that ranges from national coordination by NITI Aayog to local implementation through Panchayati Raj Institutions, making it one of the most ambitious attempts at SDG localization (NITI Aayog, 2024). India's federal structure, encompassing 28 states and 8 union territories—many comparable in size to entire countries—requires balancing national coherence with regional autonomy, offering valuable lessons for how MSPs can be adapted to diverse contexts (Vaidya & Garg, 2020). This institutional complexity, along with India's growing role as a development partner through initiatives like the India-UN Development Partnership Fund and leadership in forums such as the G20, makes the country a crucial case for examining political strategies and frameworks needed for effective SDG 17 implementation in large and diverse developing nations (UNOSSC, 2025).

Objective of the Study

This study examines India's political strategies and institutional frameworks in advancing Sustainable Development Goal 17 (SDG 17), emphasizing national coordination, fiscal reforms and multi-stakeholder partnerships. It aims to assess both achievements and challenges in aligning domestic governance with global commitments.

Methodology

The research adopts a qualitative, desk-based approach, drawing on secondary data from government reports, international organizations, and scholarly literature. Content analysis is employed to organize findings across coordination mechanisms, fiscal reforms and cooperation models. Triangulation of diverse sources strengthens reliability and provides a comprehensive understanding of India's progress on SDG 17.

POLITICAL STRATEGIES FOR SDG 17 PARTNERSHIPS

The realization of Sustainable Development Goal 17 (SDG 17), which underscores the importance of global partnerships in advancing sustainable development, is contingent upon coherent political strategies that align domestic priorities with international commitments. In the Indian context, political leadership has sought to institutionalize mechanisms for coordination, strengthen international development cooperation and implement fiscal reforms that enhance resource mobilization. NITI Aayog has emerged as a pivotal coordinating body, fostering policy alignment across states and ministries while India's active engagement in South-South cooperation reflects its broader commitment to collective global progress. Complementing these efforts, fiscal and policy innovations have reinforced financial sustainability and created enabling conditions for multi-level interventions. Together, these strategies illustrate how India positions itself as both a national driver and an international partner in advancing the 2030 Agenda.

Institutional Frameworks Supporting SDG 17 in India- National Coordination via NITI Aayog

NITI Aayog, functioning as India's apex public policy think tank, plays a central role in steering national implementation of the Sustainable Development Goals (SDGs). Its mandate goes beyond advisory functions to strategically map global targets onto India's development priorities, ensuring coherence between international commitments and domestic policies (NITI Aayog, 2020a). A key instrument in this process is the SDG India Index and Dashboard, which tracks state-wise progress while fostering cooperative and competitive federalism by benchmarking performance across states and union territories (NITI Aayog, 2021). This mechanism incentivizes local governments to innovate, adapt, and accelerate development trajectories aligned with SDG principles.

Beyond measurement, NITI Aayog convenes multi-stakeholder consultations, drafts long-term vision documents, and facilitates cross-state knowledge exchange, promoting a 'whole-of-government' and 'whole-of-society' approach (UNDP India, 2022). Its emphasis on awareness generation, institutional capacity-building and collaborative governance underscores that achieving the SDGs is not solely a government responsibility but one that requires civil society, academia, and the private sector

(Government of India, 2023). In doing so, NITI Aayog embeds sustainability within governance frameworks while advancing inclusive and participatory development models.

International Development Cooperation

India's approach to international development cooperation is grounded in solidarity, mutual respect, and shared growth, with a strong focus on South-South cooperation. A cornerstone of this engagement is the India-UN Development Partnership Fund, launched in 2017, which has committed more than $150 million to demand-driven projects across least developed countries (LDCs) and small island developing states (SIDS) (UNOSSC, 2021). By prioritizing capacity-building, technology transfer, and sustainable infrastructure, the Fund reflects India's efforts to tailor development assistance to the aspirations of partner nations.Alongside bilateral initiatives, India actively participates in multilateral platforms such as the G20, BRICS and the Commonwealth, where it advocates for a more equitable global development architecture (MEA, 2023). Regional groupings like BIMSTEC and global initiatives such as the International Solar Alliance further expand opportunities for knowledge-sharing, resource mobilization, and innovation in pursuit of the 2030 Agenda (International Solar Alliance, 2022). These efforts underline India's transition from aid recipient to development partner, reinforcing its role as a bridge between developed and developing economies.

Fiscal and Policy Reforms

India's pursuit of SDG 17 is supported by fiscal and policy reforms that strengthen domestic resource mobilization and enhance public finance management. The introduction of the Goods and Services Tax (GST) in 2017 marked a turning point in fiscal federalism, creating a unified tax regime that broadened the revenue base, reduced cascading taxes, and improved transparency (Government of India, 2017). Complementing this, levies such as the Swachh Bharat Cess linked fiscal innovation with social sector outcomes, particularly sanitation and hygiene (CAG, 2018). The Fourteenth and Fifteenth Finance Commissions further expanded fiscal devolution, empowering states with greater financial autonomy to design context-specific development programs (Finance Commission of India, 2020).Digital governance initiatives have reinforced these fiscal reforms. The Direct Benefit Transfer (DBT) system and the JAM (Jan Dhan–Aadhaar–Mobile) trinity enhanced transparency and efficiency in welfare delivery (World

Bank, 2021). These measures directly advance SDG 17.1 (domestic resource mobilization), SDG 17.3 (mobilization of additional financial resources) and SDG 17.14 (policy coherence for sustainable development). Capacity-building in public finance management has also strengthened institutional readiness, aligning fiscal reforms with broader global partnership targets.

National and State-Level Structures

India's institutional framework for SDG 17 rests on coordinated action across national, state, and local levels. At the national level, NITI Aayog ensures policy coherence while the Ministry of Statistics and Programme Implementation (MoSPI) manage the National Indicator Framework, standardizing SDG metrics and supporting states in data collection and monitoring (MoSPI, 2020; NITI Aayog, 2021). State governments complement these efforts through SDG-aligned vision documents and localized indicator frameworks, enabling tailored development strategies (UNDP India, 2022). This multi-tiered structure promotes coherence while strengthening accountability and regional ownership of the 2030 Agenda.

This layered arrangement reflects India's political strategy of aligning national priorities with local realities by embedding SDG 17 within both top-down and bottom-up mechanisms. It ensures that central directives provide the necessary guidance while empowering states and local bodies to adapt strategies according to their socio-economic contexts. Such a balance enhances institutional resilience and demonstrates how political frameworks can nurture inclusive partnerships that extend across governance levels.

Public–Private Partnerships and Private Sector Engagement

The private sector has emerged as a key partner in advancing SDG 17 through public–private partnership (PPP) models in infrastructure, climate action, trade, and technology. Initiatives with the Centre for Responsible Business (CRB) and the European Union have advanced responsible business practices, sustainable supply chains, and innovation ecosystems (CRB, 2022). Corporate Social Responsibility (CSR) mandates and Micro, Small, and Medium Enterprises (MSMEs) further integrate private actors by channeling financial resources, encouraging social entrepreneurship, and promoting technological solutions aligned with the SDGs (Ministry of Corporate Affairs, 2021).India's political framework actively leverages these collaborations as instruments of development policy. By positioning the private sector as a co-creator of sustainable solutions rather than a passive donor, the state fosters innovation while addressing financing and capacity gaps. This reflects a deliberate institutional strategy where partnerships extend beyond infrastructure to encompass social impact and knowledge-sharing, thereby enhancing the transformative potential of SDG 17.

Civil Society and Local Governments

Civil society organizations (CSOs) and local governments translate SDGs into action at the grassroots through advocacy, awareness, and capacity-building. Panchayati Raj Institutions (PRIs) promote participatory governance and community-led planning for sustainable development (UNDP India, 2022). Kerala's decentralized model is a notable example, demonstrating how bottom-up planning and community participation strengthen accountability and service delivery. However, many local bodies continue to face institutional and financial constraints, limiting their ability to fully integrate SDGs into local governance (Government of India, 2023).This dimension underlines how India's institutional frameworks embrace the principles of inclusivity and community engagement as political strategies for advancing SDG 17. By enabling CSOs and PRIs to act as catalysts of local ownership, India ensures that global goals are contextualized within community needs. Although challenges remain, the integration of grassroots actors highlights the importance of partnerships that are people-centered and rooted in democratic traditions, reinforcing the broader governance mechanisms of sustainable development.

International Collaboration and Institutional Strengthening

International partnerships reinforce India's institutional framework by enhancing access to finance, expertise, and technology. Collaboration with UN agencies, including UNDP, UNICEF, and UNEP, has supported capacity-building, policy integration, and technical assistance (United Nations, 2023). India's leadership in platforms like the G20, BRICS, and the International Solar Alliance has facilitated global knowledge-sharing and innovation, particularly in renewable energy (International Solar Alliance, 2022). These engagements align domestic reforms with global priorities, strengthening India's role in shaping the 2030 Agenda.India's strategic engagement with international actors demonstrates how political diplomacy and institutional cooperation can elevate national development agendas to the global stage. By framing itself as both a recipient and provider of development partnerships, India bridges domestic policy needs with global governance frameworks.

This dual role not only advances SDG 17 but also positions the country as a credible voice in shaping norms of sustainable development, thereby reinforcing the interconnectedness of politics, partnerships and institutions in the SDG era.

Challenges and Gaps

Despite significant institutional progress, India continues to face multiple challenges in fully operationalizing SDG 17. Limited devolution of funds, functions, and functionaries weakens grassroots ownership and accountability, leaving Panchayati Raj Institutions and urban local bodies dependent on higher tiers of government for resources. Financing gaps and shortages of skilled human resources at state and local levels further restrict the capacity to implement SDG-aligned initiatives effectively. Persistent data deficits—particularly in disaggregated and subnational statistics—hinder evidence-based policymaking and make it difficult to monitor progress across diverse regions. Institutional inefficiencies, such as delayed fund flows and uneven coordination among ministries and states, compound these issues and reduce the overall effectiveness of policy frameworks.

Equity concerns also remain significant, as marginalized communities and vulnerable groups are often excluded from decision-making processes and benefit-sharing mechanisms. While the private sector's role has expanded through CSR initiatives, impact-driven entrepreneurship, and innovation ecosystems, its contributions still lack the scale and strategic integration required to unlock the full transformative potential of partnerships. The absence of stronger alignment between corporate priorities and SDG targets limits the ability of private engagement to act as a long-term driver of sustainable development.

These gaps highlight the need for deeper political commitment to decentralization, more predictable financing streams, and institutional reforms that promote inclusivity and responsiveness. Strengthening partnerships with civil society, enhancing capacity-building at the local level, and embedding accountability mechanisms into governance structures are equally essential. Bridging these gaps is not only a question of administrative reform but also of political will to expand participation and ensure equitable development outcomes. Addressing these challenges would allow India's institutional frameworks to move beyond symbolic commitments toward more robust, integrated and transformative multi-stakeholder partnerships, accelerating the nation's progress toward the 2030 Agenda.

Conclusion

India's journey with SDG 17 shows both creative solutions and difficult gaps. Kerala's decentralized planning offers a clear example of how local participation can make global goals real in everyday governance. Digital tools such as JAM, Direct Benefit Transfers and Digital India have widened inclusion and improved transparency, while indicator frameworks designed by MoSPI have given states a stronger base for tracking progress. The India-UN Development Partnership Fund has also shown how South-South cooperation can move from ideas to impact.Still, challenges remain. Local institutions often lack funds, skilled people and reliable data, and questions of equity continue to hold back full participation. For India to move faster, stronger financing, deeper decentralization and broader partnerships will be vital. By addressing these issues and building on what already works, India can strengthen its role in global platforms such as the G20, BRICS and the International Solar Alliance, setting an example of how partnerships can drive progress across all SDGs within the 2030 timeframe.

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24.

CONTEXTUALIZING INDIA'S SUSTAINABLE DEVELOPMENT JOURNEY WITHIN ITS SOCIO-POLITICAL HISTORY

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Abstract

This article examines India’s sustainable development journey within its socio-political history, highlighting the lasting impact of colonial legacies on economic and environmental frameworks. It traces the shift from post-independence planned development to liberalization, emphasizing the role of socio-political movements like Chipko and Narmada Bachao Andolan in advancing environmental awareness and policy reforms. The integration of the Sustainable Development Goals (SDGs) into national strategies is explored, alongside challenges from demographic pressures, social inequalities, and ecological stresses. Case studies such as MGNREGA and community forest management illustrate the links between governance, social equity, economic growth, and environmental stewardship. The article also recognizes the importance of indigenous knowledge and cultural values in fostering resilience. Overall, this analysis highlights the need for adaptive governance, inclusive participation, and the blend of traditional and modern knowledge systems to promote equitable and sustainable development in India’s complex socio-political landscape.

Keywords: Sustainable Development, Socio-Political History, SDGs, Colonial Legacy & Environmental Policy

Introduction

Sustainable development, as defined by the Brundtland Commission (1987), is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This concept requires balancing economic growth, social inclusion, and environmental protection to achieve a harmonious and enduring development pathway. India's sustainable development trajectory reflects the country's complex socio-political history marked by over two centuries of colonial rule, the subsequent struggle for independence, and the establishment of democratic governance practices. The diversity of India's cultures, regional disparities, and evolving political ideologies add layers of complexity to its developmental path. Understanding India's sustainability challenges and approaches thus necessitates an examination of its historical legacies—such as colonial economic and environmental policies—and the influence of socio-political movements and policy reforms post-independence that progressively incorporated environmental concerns into broader developmental frameworks (Rashmi & Thippesh, 2023; Research and Information System for Developing Countries [RIS], 2016; Brundtland Commission, 1987).

India's social and political fabric has been characterized by efforts to confront and reduce entrenched inequalities, promote inclusive growth, and address large-scale ecological challenges. The Indian Constitution supports social justice, securing rights and protections for marginalized groups like Scheduled Castes, Tribes, and minorities, and fosters democratic decentralization through Panchayati Raj institutions to enhance local governance and participation (Rashmi & Thippesh, 2023; Bhattacharyya et al., 2024). The economic liberalization starting in the 1990s ushered in new opportunities for growth while simultaneously exacerbating socio-environmental stresses, highlighting the urgent need to align rapid development with sustainability goals (Rashmi & Thippesh, 2023; Bhattacharyya et al., 2024). Subsequently, India's adoption of the United Nations Sustainable Development Goals (SDGs) in 2015 marked a convergence of global commitments with national priorities reflecting the country's socio-political realities (RIS, 2016; Bhattacharyya et al., 2024). This article delves into these intertwined historical, social, and political contexts to better understand India's sustainable development journey and the ongoing policy responses to reconcile growth, equity, and environmental stewardship (Rashmi & Thippesh, 2023; RIS, 2016; Bhattacharyya et al., 2024).

Historical Foundations and Colonial Legacies

The colonial period in India, which lasted from 1757 to 1947, had a big impact on the environment, economy, and society. The British rulers focused on taking natural resources like forests and minerals mainly to benefit their own empire. They built roads, railways, and other infrastructure to help move these resources to ports for export. Unfortunately, this often-harmed India's environment. For example, many forests were cut down to make space for commercial farming or to get timber. This destroyed traditional ways that local people used to care for nature in a sustainable way. The British policies also caused many local people to lose their land and homes, hurting their social and economic well-being (Rashmi & Thippesh, 2023; United Nations, 2015).

After India became independent in 1947, it faced the difficult task of recovering from the damage caused during colonial rule. The country inherited an economy that was not developed equally, with many poor people and limited resources left behind. The laws and systems set up by the British, especially related to forests and land ownership, were still in place. These laws sometimes made it difficult for local communities to manage their natural resources freely. The government had to deal with these challenges while also working towards development and social justice. This created some of the first political and social difficulties India faced when trying to build a sustainable future (Rashmi & Thippesh, 2023; Research and Information System for Developing Countries [RIS], 2016).

At the same time, many people started to fight against unfair policies and environmental destruction. Tribal groups, peasants, and local communities stood up to protect their land and forests. One famous example is the Chipko Movement, were villagers, especially women, hugged trees to stop them from being cut down. This showed that communities could use their traditional knowledge about nature along with demands for fair treatment and social justice. These movements helped change the way India looked at environmental protection and influenced laws and policies to be more inclusive and caring towards both people and nature (Rashmi & Thippesh, 2023; United Nations, 2015).

Post-Independence Socio-Political and Economic Policies

After gaining independence in 1947, India started a planned approach toward development focusing on industrialization, improving infrastructure, and reforming agriculture. This approach was based on Nehruvian socialism, which aimed at self-reliance and reducing poverty through state-led growth. The government introduced Five-Year Plans that mainly supported heavy industries and manufacturing, trying to build a strong economy. However, in this focus on growth, environmental issues were often overlooked as economic progress was the biggest priority (Rashmi & Thippesh, 2023; Bhattacharyya et al., 2024).

India also worked to promote social justice and inclusion by building these values into its Constitution. Policies focused on uplifting marginalized communities such as Scheduled Castes, Scheduled Tribes, and religious minorities by improving their access to education, health care, and economic opportunities. Decentralization was promoted by strengthening Panchayati Raj institutions, which allowed local rural communities to take part in decision-making. This local participation helped make development efforts fairer and more inclusive for disadvantaged groups (Rashmi & Thippesh, 2023).

Starting in the 1990s, India introduced economic liberalization, opening the country to global markets and encouraging private enterprise. This led to faster economic growth and more foreign investment but also caused new social and environmental challenges. Industrial expansion and urbanization increased pollution and strained natural resources. At the same time, social inequalities remained significant. These factors created a push for policies that balance economic growth with social equity and environmental protection, highlighting ongoing challenges for sustainable development in India (Rashmi & Thippesh, 2023; Bhattacharyya et al., 2024).

Environmental Awareness and Socio-Political Movements

During the 1970s and 1980s, environmental awareness in India grew significantly through grassroots struggles and social movements that challenged harmful development projects. One of the most well-known movements was the Chipko Movement, where local villagers, especially women, hugged trees to prevent them from being cut down. This movement was not only about saving forests but also about involving communities directly in protecting their environment. The participation of local people helped push the government to create policies that recognized the importance of forests and community rights. The Chipko Movement influenced national laws and paved the way for forest rights legislation, emphasizing that environmental conservation should include the voices of those who depend on natural resources for their livelihoods (Rashmi & Thippesh, 2023).

Another major movement was the Narmada Bachao Andolan, which opposed the construction of large dams on the Narmada River. This movement raised concerns about the displacement of communities and the destruction of ecosystems caused by dam projects. It highlighted the conflicts between large-scale development and the rights of people and nature, pushing for more balanced and sustainable approaches. These socio-political movements stressed the importance of participatory governance, where affected communities have a say in decisions impacting their environment and lives. In response to these growing concerns, the Indian government introduced important environmental laws such as the Wildlife Protection Act (1972), Forest Conservation Act (1980), and made Environmental Impact Assessments mandatory for major projects. These legislative measures aimed to embed social and political concerns into environmental governance, marking a shift toward more sustainable and equitable development practices (Rashmi & Thippesh, 2023).

Integration of Sustainable Development Goals (SDGs) into National Policy

India officially adopted the United Nations Sustainable Development Goals (SDGs) in 2015, signaling a commitment to achieving global sustainability targets while addressing the country's own developmental needs. These SDGs cover a broad range of issues including climate change, clean energy access, ending poverty, improving healthcare and education, and promoting gender equality. The government aligned these global goals with existing national missions and policies to create a cohesive framework for sustainable development. One key initiative preceding the SDGs was the National Action Plan on Climate Change (NAPCC), launched in 2008, which included eight missions focused on promoting solar power, enhancing energy efficiency, encouraging sustainable agriculture, and conserving water resources. These missions laid the groundwork for integrating sustainability in economic planning and policy implementation throughout India (Ministry of Environment, Forest and Climate Change [MoEFCC], 2019; United Nations Development Programme [UNDP], 2019).

The implementation of the SDGs in India is primarily coordinated by NITI Aayog, a policy think tank of the Government of India. NITI Aayog works through a decentralized governance structure that involves various stakeholders including central and state government agencies, civil society, and the private sector. This multi-stakeholder approach is crucial given India's vast socioeconomic diversity and complex federal political system. The government's efforts focus on inclusive growth strategies encompassing poverty reduction, infrastructure development, and social inclusion programs that reach marginalized populations. Recognizing that different regions face unique challenges, NITI Aayog emphasizes state-specific approaches to balance economic development with environmental protection and social equity. This ensures that the SDGs are not treated as uniform targets but are adapted to local contexts and priorities (NITI Aayog, 2017; World Bank, 2020).

Despite these efforts, India faces several challenges in achieving the SDGs fully. Data collection and monitoring mechanisms need strengthening to capture accurate and timely information across the country, which is critical for evaluating progress and identifying gaps. Regional disparities persist, with some states lagging in health, education, and infrastructure indicators compared to more developed areas. Additionally, integrating economic growth with environmental sustainability remains a delicate balancing act as rapid industrialization and urbanization often come with increased pollution and resource depletion. Addressing these challenges requires innovative policy solutions, increased investment in green technologies, and enhanced coordination among government, civil society, and private sectors to ensure that development is sustainable, equitable, and inclusive for all Indians (Jain & Singh, 2018; OECD, 2018).

Socio-Political Challenges in India's Sustainable Development

India faces multiple interconnected socio-political challenges that complicate its path toward sustainable development. Rapid population growth and increasing urban migration place significant pressure on infrastructure and the country's natural resources, leading to overcrowded cities and resource depletion. Persisting issues such as poverty, malnutrition, illiteracy, and gender inequality continue to weaken social outcomes and amplify disparities within society. Furthermore, there are stark regional differences in development, partly due to uneven policy implementation and varying governance capacities across states. Environmental problems, including air and water pollution, deforestation, and the loss of biodiversity, threaten both ecosystems and public health nationwide. These challenges are further complicated by political and economic trade-offs, as developmental growth objectives sometimes conflict with the need for environmental conservation. To effectively address these problems, India requires inclusive governance models that account for its diverse socio-political context and emphasize evidence-based, participatory, and flexible policymaking approaches that can adapt to evolving challenges (Jain & Singh, 2018; OECD, 2018; World Bank, 2020).

Case Studies: Implementing Sustainability through Socio-Political Inclusion

India has implemented several key initiatives that promote sustainability through socio-political inclusion. The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) guarantees rural employment while focusing on creating sustainable assets such as water harvesting structures, afforestation, and soil conservation, thereby enhancing livelihood security and ecological restoration. Self-Help Groups (SHGs), particularly empowering women, play a vital role in fostering social inclusion by mobilizing communities and providing access to microfinance, which supports sustainable livelihoods. Additionally, community forest management has gained recognition through legislation that integrates traditional forest knowledge with formal policy frameworks, empowering indigenous communities and promoting both ecological resilience and social equity. Together, these programs exemplify how inclusive governance and local participation can drive sustainable development in India (Rashmi & Thippesh, 2023).

Role of Indigenous Knowledge and Cultural Practices

Indian cultural philosophies deeply emphasize living in harmony with nature, reflecting a worldview that sees humans as an integral part of the natural environment. Traditional practices such as maintaining sacred groves, practicing rainwater harvesting, and preserving crop biodiversity are key examples of indigenous knowledge that contribute significantly to environmental sustainability. These time-tested methods help conserve biodiversity, enhance soil and water conservation, and promote resilience against climate variability. Increasingly, India's policy frameworks recognize the importance of these indigenous knowledge systems as vital components for building climate resilience and maintaining ecological balance. The enduring philosophy of "Vasudhaiva Kutumbakam" — meaning "the world is one family" — embodies core values of interconnectedness, social harmony, and environmental stewardship, and serves as a moral and cultural foundation anchoring India's socio-ecological approach to sustainable development

Future Directions and Policy Recommendations

Future directions for India's sustainable development focus on enhancing decentralization and fostering active community engagement to attain localized and context-specific sustainability results. Policies need to better include gender and social equity issues so that development is fair to everyone, including those who are already on the outside. Promoting green technologies that work well with traditional knowledge systems can lead to long-term solutions that are based on what is real in the area. To find and fix differences between households and regions more accurately, we need to improve how we collect and monitor data. This will allow for more targeted and effective interventions. Encouraging public-private partnerships that fit with Sustainable Development Goal (SDG) financing mechanisms and corporate social responsibility can help use resources and expertise more effectively. Also, it will be important to do regular climate vulnerability assessments and come up with adaptive resilience strategies that fit India's different social and political situations in order to deal with new environmental and social problems.

Conclusion

India’s sustainable development journey is intricately linked to its socio-political history. Colonial legacies, democratic reforms, social movements, and economic policies collectively shape its sustainability trajectory. Balancing economic growth, social justice and environmental conservation remains a complex challenge requiring adaptive governance, inclusive participation, and integration of traditional and modern knowledge systems to realize the Sustainable Development Goals effectively.

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