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Sustainable Livelihoods through Agri-Innovation: India's Rural Future

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ABSTRACT

India's rural economy is deeply rooted in agriculture, with majority of the population still sourced livelihood from the sector, even though traditional farming practices limit the extent of productivity and definite income security. The rising concerns on climate changes, population expansion and changing dimensions of market challenges the rural livelihoods, and the agricultural-innovation is one of the emerging transformative pathways towards rural sustainability and prosperity. This article attempts to examine the changing dimensions of Indian agriculture in view of the new innovative farming practices, digitization processes that impacted well-being and sustainable livelihood of rural poor. The main premise is how innovations in agricultural practices led to sustainable agriculture through sustainable livelihoods of farmers, regenerative farming practices, digitalization processes and increase in environmental awareness in view of the global climate change and global warming goals.

Keywords: *Sustainable Agriculture, Agricultural Innovations, Regenerative Farming, Sustainable Livelihood.*

Introduction

Against the backdrop of global challenges of climate change, dwindling natural resources and food security to fed the increasing global population, innovations in agriculture is pressing attention towards a regenerative farming practices for sustainable livelihood through agriculture. Innovations in agriculture include development of new model, product affordable products, services, accessibility to finance, design by incorporating the existing idea or concept, use of new technologies, digitization platforms, that aids agricultural productivity, increase livelihood and income source, creation of job opportunities along with environmental awareness, etc. Innovation in agricultural sector is significant not only for agricultural productivity, but also to increase the subsistence income levels of the farmers, and for sustainable agricultural practices for accountability to environmental impacts. Though Indian agriculture has recorded significant progress in the last four decades, it is no exception to slow productivity, high input costs, low profitability, climate-risks, fluctuations in prices and market volatility for farmers. Unlike the traditional farming practices, modern farming techniques used methods with technological advancement such as use of artificial intelligence, precision farming technique, vertical farming practices and most recently agri-tech methods with a view to increase efficiency, optimal use of the scarce resources, optimal yield and addressing environmental impact of agricultural practices on climate change as well as threats to food security. This calls for an imperative approach towards optimal and efficient application of modern farming practices to farmers with literacy and awareness of new modern techniques of production processes. This article attempts to examine the changing dimensions of Indian agriculture with the adoption of new innovative farming practices and its significant impact on well-being as well as sustainability in livelihood

of rural poor. The main aim of the paper is to find out the association between innovations in agricultural practices and its impact on yield productivity, that adds to livelihood and sustainability of poor farmers in rural areas. Innovations in agriculture in the form of modern technologies such as precision farming practices; digital platforms for mandis for common price setting; climate smart practices that help farmers to forecast and predict their farming plans and production; farmers are able to increase crop yields; reduction in cost of inputs and operational efficiency; and minimize post-harvest losses, etc emerges as cornerstone for building sustainable livelihoods in rural India. These innovations not only enhance productivity of agriculture, but it also diversity the sources of income through allied activities to farmers. In other words, digitization has made easier with digital tools empowering rural communities in connecting one another directly or indirectly across farmers as well as markets, improvement in accessibility to credit and crop insurance, empowering women and participation of youths in agri-startups. Overall, these advancements are reshaping rural India into a more resilient, inclusive, and prosperous economy, thereby ensuring farmers in the sector and agriculture remains both a livelihood and a sustainable future.

The article has seven sections. Section II gives a brief review of literature on the extant issues. Section III highlights the changing dimensions of Indian agriculture in the context of information and technology. Section IV provides objectives of the study, data and hypotheses. Section V gives the major framework and findings respectively. The last Section concludes.

A Brief Review of Literature

Literatures on agriculture and its significance to diverse perspectives of the economy has been carried out across time and space. Over the period, researchers also examined technological innovations in agriculture and its role in building sustainable farming practices for sustainable livelihoods to poor farmers; how adoption of modern farming practices helps in the mitigation of climate change or reducing environmental impacts; and very significantly, the extent of sources and availability of agricultural credits across farmers. As smallholder farmers are unable to capture proportionate value for their produce because of low visibility of demand, exploitation by intermediaries, limited access to low-cost logistics and low bargaining power; technology has potentials for solution to these farmers through creation of creating cost efficiencies, transparency in information flows, thereby strengthening connectivity between value chain actors **(World Economic Forum, 2021)**. Agricultural sustainability in India calls for a multi-dimensional food system which continues producing enough food calories while impounding carbon, protecting biodiversity and ecosystem services, and supporting rural livelihoods **(Bawa & Seidler, 2023);** agricultural sector can benefit significantly from increased access to Big Data **(Shankarnarayan & Ramakrishna, 2020);** with delivery of agricultural information is a viable policy option for enhancing productivity of agriculture **(Krishna & Naik, 2020)**. Recent initiatives by World Economic Forum on AI4AI (Artificial Intelligence for Agriculture Innovation) is one of the most successful implementations in agriculture sector; a sample pilot project '*Saagu Baagu*' developed in partnership with Telangana state government in Khammam District, which substantially improved the chili value chain for more than 7000 farmers **(World Economic Forum, 2024)**. Some of the major developments of digital platforms in Indian agriculture are – e-NAM (unified national level market platform), Remote Sensing and Geo-tagging, 'Gramseva: Kisan' app (Mandi price on real time basis), movable warehouses and cold storages, solar powered irrigation, mobile-based applications to cater the specific needs of farmers, etc. among others **(RBI, 2019)**. No doubt, successful implementation of innovations in agricultural practices has positive outcomes both to producers and consumers, provided challenges on cost, accessibility, technical assistance and cope with changing dimensions are addressed at the fundamental framework. To say, empowering the farmers through success of digital agriculture in India depends on attributes such as – affordability of technology use, accessibility and easy use, maintenance and handling of systems, timely grievance redressal mechanism and appropriate policy support **(Balkrishna et al. 2023)**. Government and regulatory bodies have, over the period, taken up significant schemes and steps towards resilience to climate change, focusing on the areas that is sensitive to such ailments. For the smallholder farming communities, government schemes as well as government support in terms of extension services and subsidies are vital components of rural farming households' climate change adaptation strategy **(Tanti et al., 2022);** switching from chemical to sustainable inputs demands an autonomous investment by the state to increase capacity and enhance affordability **(Paul et al, 2023)**. NICRA project attempts to develop and promote climate resilient technologies in agriculture, covering climatically most vulnerable 151 areas of the country which is prone to extreme weather conditions like floods, droughts, frost, heat waves, etc. **(ICAR, 2018)**. The availability of agricultural credit is significant in meeting the goals of sustainable agriculture. According to the NABARD all India Financial Inclusion Survey, (NAFIS) Report 2016-17, 72 percent of credit requirements of agricultural

households are from the institutional sources, the rest 28 percent from non-institutional sources **(RBI, 2019)**. Further, there is inter-state variations in the distribution of agricultural credit. Even though the government along with the regulatory authorities have taken up several initiatives, schemes like loan waivers announced by the government affected the credit culture in the country as many borrowers withhold repayments, e.g. NPA of 8.44 percent as on March 31, 2019 in the agriculture sector, all these discouraged the scheduled commercial banks for sanctioning fresh loans to such farmers. Financial literacy, financial inclusion along with skilled development, training, application of digitization procedures in agricultural practices are necessary and prerequisite for the farmers to sustain their livelihoods and contribution towards sustainable agriculture system in the country at large.

Changing Dimensions in Indian Agriculture

The Indian agriculture has made a significant progress in terms of the method of production and the baskets of lists of agricultural produce for domestic use as well as for export earnings. Farmers faced with multiple challenges from meeting supply chain in food production to go in pace with digitization processes and awareness of environmental impacts in view of the current global scenario of climate change and meeting sustainable development goals. Digitization has impacted significantly the process of agricultural production and unprecedented challenges to farmers meet the market demands.

- **Digitization in Agriculture**

Digitization of agriculture refers to integration of digital technology in production processes of agricultural activities. Chart 1 explains the basic conceptualization on digitization in agriculture practices and its impact on development of Indian agriculture. Level 0 is associated with new agricultural strategy in which farmers used same agricultural model of production, same factor intensity, under the given market size of final produce, but added digitization in operation of agricultural activities such as compulsory registration, digitalization of land records, documentations, access to finance under digital platform, which incurs cost in initial stages though there is an increase operational efficiency. Level 1, advanced digitization process under new digital platforms for farmers are available with increase in transparency and revenue earnings, such as e-NAM provides a uniform price of mandis, farmers in a particular region are equally receiving the prices of agricultural produce, easily access to credits, rents for equipment, storage facilities. In Level 2, farmers are aware of new marketing skills to promote their products through various new channels of distribution and Omni-channels method. Level 3 is associated with new agricultural products and enhanced marketing coverage. Level 4 comes with new business model, in which new agri-tech business model like precise farming, regenerative farming practices, use of artificial intelligence, innovative product designs to reduce agricultural wastes of resources, innovations like agri-tech methods and sustainable agricultural practices. Modern agricultural practices encompass digitization processes for increase in productivity, profitability and operational efficiency. Government initiatives and agriculture program database to mention are - soil health cards, eNAM sales records, crop insurance services, mKisan and KCC engagement. Initiatives such as mKisan SMS Portal for farmers provides information and consultative services to farmers through SMS in their language, preference of agricultural practices and location.

- **Soil Health Cards**

Soil Health Card (SHC) scheme is a government of India scheme for farmers to check soil nutrient status of his holding and advise him on the quantity of fertilizers as well if required amendments in soil to maintain soil health in the long-run. It is available once in a cycle of 3 years, able to record the changes in soil health for the subsequent period. As per the data shown in Table 1, 253 lakh soil samples will be tested in each cycle and issuing approximately 14 crore SHC and there are gradual increase samples collected, tested and card issued in cycle II. This new scheme helps farmers to maintain soil quality and aid in agricultural productivity.

Table 1: Status of Soil Health Care (SHC) Scheme in India

Periods	Sample Collected	Sample Tested	SHC Printed	SHC Dispatched
Cycle I (2015 to 2017)	25349546 *(100.00)*	25349546 *(100.00)*	107412648 *(100.00)*	107412648 *(100.00)*
Cycle II (2017 to 2019)	27786235 *(101.46)*	27415707 *(100.02)*	121926302 *(94.21)*	121926157 *(92.24)*
Model Village (2019 to 2020)	2143345 --	2140768 --	2371552 --	2371552 --

2020-2021	1153132 --	1153132 --	1152037 --	1152037 --
2023-2024	6614389 --	3929831 --	229554 --	2295542 --

Source: https://soilhealth.dac.gov.in/home

- **Crop Insurance**

Crop Insurance Schemes of the government of India – Pradhan Mantri Fasal Bima Yojana (PMFBY) & Restructured Weather Based Crop Insurance Scheme (RWBCIS) provides insurance services to farmers with an integrated IT solution under web-based ecosystem for fast delivery, unite fragmented databases and aims to mitigate the insured farmers against the probability of financial lox resulting from adverse weather conditions. This led to comprehensive view of data in a secure environment, accessibility of information to various stakeholders – governments, regulatory bodies, insurance companies, financial intermediaries, bankers, farmers and social communities. Table 2 reveals that out of the total farmers' insurance applications, more than 90 percent are insured in terms of area holdings; percentage of claims paid is fair and almost 95 to 100 percent across the periods for both kharif and rabi crops. Further, with the help of this scheme, farmers' information and details are available state-wise, can protect financial loss of farmers associated with weather uncertainties and crop damages by pests/insects.

Table 2: PMFBY & RWBCIS Combined - Aggregate Business Statistics

Periods	Farmers Applications Insured (Lakh)	Area Insured (Lakh ha)	Sum Insured	Farmers Share in Premium	Gross Premium	Reported Claims	Paid Claims	Farmer Applications Benefitted (Lakh)
			Rs. Crore					
2016-17	583.7	561.1	203110	4078	21654	16809	16809	156.5
2017-18	532.7	507.7	202282	4204	24670	22127	22118	176.8
2018-19	577.2	525.8	229598	4773	29036	29250	28129	222.6
2019-20	612.9	501.0	219040	4502	32022	26893	25822	223.6

Source: https://pmfby.gov.in

- **eNAM Platform**

Currently there are 1389 markets that are linked to the e-NAM network from 23 states and 4 union territories as against 1000 markets under e-NAM platform in 2020, covering 18 states and 1 union territory. Government of India incentivized the states to onboard select mandis into e-NAM, single trading license given across the states, single point levy of market fee in the state and facilities for electronic auction for price fixing. It provides a unified national market for agriculture produce through integration of markets, removing information asymmetries between buyers and sellers, fixing price based on actual demand and supply as well as promotes transparency in the auction process, and access to a nationwide market for the farmer. Data of all the participants are registered in the platform, bids of prices of more than 150 agricultural products are available based on price fluctuations in CPI from time to time. Table 3 shows the number of registered traders and unified licenses issued under the eNAM as on 2024, and significant progress has been made in the composition of stakeholders and states covered.

Table 3: Number of Registered Traders and Unified Licenses Issued, as on 31st March, 2024

States/UTs	Mandis registered on eNAM	Registered stakeholders on e-NAM			
		Traders	Commission Agents (CAs)	Farmer Producer Organizations (FPOs)	Farmers
Andaman and Nicobar Islands	1	4	0	0	1
Andhra Pradesh	33	3771	2331	273	1452409
Assam	3	8	0	21	31
Bihar	20	604	0	91	2146
Chandigarh	1	121	119	0	7108
Chhattisgarh	20	3476	237	58	135868
Goa	7	877	0	5	911

Gujarat	144	10143	7157	230	869729
Haryana	108	16849	29618	266	2725669
Himachal Pradesh	38	2309	1158	88	125293
Jammu & Kashmir	17	2652	211	48	48066
Jharkhand	19	2499	0	194	266438
Karnataka	5	748	806	24	1513
Kerala	6	430	0	37	3084
Madhya Pradesh	139	24960	0	167	3023106
Maharashtra	133	22300	17815	338	1227890
Nagaland	19	177	0	0	164
Odisha	66	9255	0	448	378403
Puducherry	2	218	0	3	13601
Punjab	79	3050	9459	20	217645
Rajasthan	145	84890	26727	288	1507462
Tamil Nadu	157	10999	0	237	423470
Telangana	57	6249	5091	119	1823930
Tripura	7	23	0	2	38
Uttar Pradesh	125	39329	8571	356	3304471
Uttarakhand	20	5830	2699	102	91197
West Bengal	18	5075	125	270	78719
Total	**1389**	**2,56,846**	**112124**	**3685**	**1,77,27,480**
Total (May, 2020)	**1000**	**1,28,478**	**70,969**	**1005**	**1,66,18,683**

Source: https://enam.gov.in/web/dashboard/stakeholder-data

- **Sustainable Livelihood**

Livelihood includes the assets, resources, capabilities and human activities that is means for survival and living; sustainable livelihood is a state in which livelihood sustains consistently in that we are able to protect against any financial and economic shocks, environmental forces/ damages, opportunities of benefiting people around remain continue with next generation at local and global levels. Sustainable agriculture is a practice of farming in which farmers work with natural processes to conserve resources through minimizing wastes and reducing environmental impacts. In other words, sustainable agricultural practices call for a regenerative farming practices such as composting, organic farming, maintaining the fertility of soil through various cropping methods, afforestation and sensitive to environmental impacts. NABARD has taken up several initiatives towards rural prosperity and for sustainable livelihood through diverse perspectives.

Table 4: Summary of Case Studies on Sustainable Livelihood Programs Initiated by NABARD

Programs	Beneficiaries	Initiatives	Impact
The Fruit of Prosperity	The Nishi tribe of Papum Pare district, Arunachal Pradesh	Promotion of sustainable livelihoods	Scale up horticulture farming; & Improvement in the social and economic well-being of tribals.
A Mushroom Revolution	Small/marginal farmers and landless labourers of Jamui District, Bihar	Encouraging innovative livelihood options	Over 150 beneficiaries engaged in the activity throughout the year; viable spawn centre in the village; assured market for mushrooms.
Green Warriors	Calicut International Airport and the entire Malabar region of Kerala	Environment awareness at the grass root level	Organic waste converted into manure; plastic waste segregation; set up of bio-gas unit; & clubs earn 50,000 per month.
Prawning Wastelands	Farmers of uncultivable wastelands in Rohtak district, Haryana	Prawn cultivation in saline affected wastelands	Conversion of wasteland to cultivable lands through prawn cultivation in saline affected areas; selling shrimps in markets in Delhi.
One Stop Solution	Farmers with small holdings in Kannur district, Kerala	Encouragement of Intensive Integrated Vertical Farming	Ensures maximum production from minimum space; easy-to-replicate model that promotes integrated farming system and generates income all through the year.

Agrovention	Youth of Tapola village, Satara district, Maharashtra	Support to entrepreneurial aspirations of educated rural youth	Employment opportunities for villagers; accommodates 3,000 tourists yearly at nominal rates; provides various entertainment activities like kayaking, swimming, trekking and visits to strawberry farms.
Herbal Solution	Residents of Idukki, Kottayam and Ernakulam districts, Kerala	Use of organic products in rural India	Creation of production units; product diversification in terms of oil, paste, etc.; supplementary source of income for women trained in making mosquito repellents.
Creating a Buzz	Beekeepers in Kottayam district, Kerala	Promotion of meliponiculture through Farmers Clubs	Hives owned by farmers has increased; some farmers have up to 2000 hives against 15-20 hives owned by meliponiculturists in their homestead farms.
Wealth in the Backyard	Poultry farmers & consumers in Pathanamthitta district, Kerala	Establishment of a model hatchery unit	Encouraged the rearing of improved varieties and supported more than 2,500 rural families; substantial increase in egg production.
Reviving a Sweet Tradition	Farmers and villagers of Kullu, Lahaul & Spiti valley in Himachal Pradesh	Encouragement of beekeeping as a livelihood option	Up to 250% increase in fruit production in the orchards of project beneficiaries; increase in income and better lifestyle for farmers
Daily Wages to Entrepreneurs	Empowering women of Samarpur village, Mehsana district, Gujarat	Disbursement of small livelihood loans	Increased in Assets owned; & annual earnings have increased through sale of milk and cattle feed besides agricultural labour.
Inclusive Tourism	Residents of 4 villages in Puri district, Odisha	Development of community-based rural eco-tourism	Rural eco-tourism as an alternate livelihood option; substantial check in environmental damage; increase in financial inclusion and an entrepreneurship.
Powering Production, Empowering Women	Farmers and villagers in Tamenglong district, Manipur	Providing innovative livelihood options to women	Livelihood opportunities for women; tangible increase in their income; improvement in production quality and efficiency of turmeric processing; end of post-harvest losses

Source: NABARD.www.nabard.org/casestudies-new.aspx

Table 4 depicts sustainable livelihoods program taken up by NABARD in different regions of the country from time to time. It is seen from the table that the government along with NABARD has taken up initiatives towards empowering and making economically viable for farmers engaged in different agricultural innovation activities, a drive towards rural sustainability and economic uplifting by providing directions towards optimal production and increase in productivity. The schemes have significantly benefitted the small and marginal farmers, encouraging for innovative livelihood options, promotion towards sustainable livelihood, awareness towards environment, integrative approach and building entrepreneurships across different districts in different states of the country.

Objectives of the Study and Data Source

In view of the significance of digitization and technological development in the agricultural sector, it is pertinent to explore the extent of impact of agricultural innovations and improvement in infrastructures to facilitate such development towards agricultural productivity. The main objectives of the present study are – (a) To overview the progress of Indian agriculture in terms of digitization and innovations in agricultural practices (b) To highlight the various initiatives undertaken by the government and regulatory authorities for sustainable livelihood and (c) To examine the impact of changing dimensions of Indian agriculture on output productivity/performance. Accordingly, the following hypotheses are formulated to examine the changing perspectives of Indian agriculture and its total output productivity.

Null Hypothesis (H0): *There is no significant improvement in the total output productivity of agriculture with the use of modern technology and digitization in agricultural production.*

Alternative Hypothesis (H1): *There is significant improvement in the total output productivity of agriculture with the use of modern technology and digitization processes in agricultural production.*

The above hypotheses stated how the nature of association between the extent of agricultural output productivity and applications as well as use of various inputs, including technologically innovative products, mobile as by product of technology and have impacted on the overall productivity during the study period. Data are sourced from secondary database, compiled from various reports of the Reserve Bank of India, NABARD, Ministry of Agriculture, gathered for different time span, World Bank database on world development indicators for the specified period. Variables taken include – total agricultural production of all food grains, yield per hectare, area under cultivation, various inputs including use and consumption of fertilizers, pesticides, net irrigated area for the period from 2007-08 to latest available data 2024-25, wherein for certain inputs, data is available till the period 2023-24. Data on the number of mobile subscriptions per 100 people and infrastructure on supply of electricity in rural areas are also added to explain the basic facilities of infrastructure in rural India.

Analysis and Interpretation

This section provides the information and data on agricultural production of all food grains for the study period 2007-08 to 2024-25 explained by agricultural outputs, inputs and infrastructure facilities in rural India. From Table 5, it is discernible that agricultural production has drastically increased from 2308 lakh tonnes in 2007-08 gradually over the period, reaching 2975 lakh tonnes in 2019-20 to 3540 lakh tonnes in 2024-25. Similar picture is also seen in yield per hectare that has increased from 1860 hectare in 2007-08 to 2578 in 2024-25. These results are also reflected in the indices of numbers of area, numbers of production and number of yields of food grains, which has gone up significantly over the period and reached 125.40, 167.50 and 133.60 respectively. In fact, we can say that productivity in agriculture has increased over the period, though not drastically as indicated by the parameters of agricultural outputs taken.

Table 5: Agricultural Production and Inputs used for the Period 2007-08 to 2024-25

Period	Production (lakh tonnes)	Yield per hectare (kg/hectare)	Index Numbers of Area (weights=100)	Index Numbers Production (weights=100)	Index Numbers Yield of Food grains (weights=100)
2007-08	2308.00	1860	102.10	107.00	104.80
2008-09	2345.00	1909	103.40	107.00	103.50
2009-10	2181.00	1798	102.10	102.70	100.60
2010-11	2445.00	1930	109.10	121.00	110.90
2011-12	2593.00	2078	109.80	124.30	113.20
2012-13	2571.00	2129	108.90	124.20	114.00
2013-14	2650.00	2101	112.30	129.80	115.50
2014-15	2520.00	2070	111.90	124.00	110.80
2015-16	2515.00	2056	111.60	120.80	108.30
2016-17	2751.00	2129	112.60	132.80	117.90
2017-18	2850.00	2235	112.70	139.40	123.70
2018-19	2852.00	2286	113.50	138.10	121.70
2019-20	2975.00	2343	115.90	145.50	125.60
2020-21	3107.40	2394	119.90	154.10	128.60
2021-22	3156.20	2425	121.90	158.00	129.60
2022-23	3296.90	2494	125.60	165.20	131.50
2023-24	3323.00	2515	124.50	162.10	130.20
2024-25	3539.60	2578	125.40	167.50	133.60

Source: RBI (2025): Handbook of Statistics on Indian Economy. www.rbi.org.in

Table 6: Inputs in Agricultural Production and basic Infrastructure in Rural India for the Period 2007-08 to 2024-25

Period	Area under cultivation (lakh hectares)	Consumption of Fertilisers (N+P+K) (lakh tonnes)	Consumption of Pesticides (Technical Grade Material) ('000 tonnes)	Net Irrigated Area (Area in Lakh Hectares)	Mobile cellular subscriptions (per 100 people)	Access to electricity, rural (% of rural population)
2007-08	1241	225.7	41.6	631.90	28.72	57.30
2008-09	1228	249.1	43.9	636.40	42.85	63.50
2009-10	1213	264.9	41.8	619.50	60.49	65.70
2010-11	1267	281.2	55.5	638.70	70.87	65.70
2011-12	1248	277.9	53.0	660.10	67.63	68.40
2012-13	1207	255.4	45.6	665.90	68.40	72.30
2013-14	1260	244.8	60.3	684.20	71.94	72.40
2014-15	1220	255.8	56.3	685.80	75.38	76.80
2015-16	1232	267.5	56.7	677.70	83.92	79.40
2016-17	1292	259.5	58.6	692.70	85.97	83.40
2017-18	1275	265.9	63.4	701.60	85.55	85.30
2018-19	1248	273.8	59.7	722.40	82.90	88.30
2019-20	1270	293.7	61.7	754.70	82.25	93.90
2020-21	1298	325.4	62.2	777.30	81.60	93.80
2021-22	1302	298.0	58.7	779.20	80.18	95.20
2022-23	1322	298.4	53.6	793.10	80.56	99.30
2023-24	1321	306.4	--	824.20	79.35	--
2024-25	1373	--	--	--	--	--

Source: RBI (2025): Handbook of Statistics on Indian Economy. www.rbi.org.in &
World Bank Database - World Economic Indicators. www.worldbank.org

Table 6 explains the traditional inputs utilized in agriculture in the production process of agricultural output. Area under cultivation has a slight change, but more or less it hovers around 1300 lakh hectares in the recent past five years. Consumption of fertilizers as inputs has increased gradually from 225 lakh tonnes in 2007-08 to 306 lakh tonnes in 2023-24. Significant improvement is seen in terms of net irrigated area. These are the major inputs utilized in the production of agricultural output, further agriculture also depends on the vagaries of monsoon, climate changes and availability of funds or resources to conduct agricultural activities during and post-harvest periods. Data on the number of mobile cellular subscriptions per 100 people is integrated to reflect the impact of digitization and its impacts to people in rural India towards seeking information of products, mandis and availability of digital loans, payments and

transactions, delivery of messages from government for any schemes, benefits, or awareness of products and services related financial literacy. It is seen that over the period the coverage of mobile cellular subscriptions has increased, from 29 percent in 2007-08 to almost 80 percent subscriptions in 2024-25. The use of mobile phones, specifically smart phones enable farmers to access information and data on agricultural related things and also towards building strong financial inclusion with preparedness for any sort of financial and economic shocks that may happen in uncertain contingencies and even alert from crop failure with the help of crop insurance/cattle insurance, etc. Data on rural electricity supply also indicated that almost 100 percent coverage in rural India, which is one of the important sources for household survival and in dealing with power supply needed for agricultural activities such as irrigation, pump sets and appliances in general. As also explained in the previous section that digitization has made the enhancement of financial inclusion in rural areas in terms of the number of bank accounts opened, uses for utility bills, awareness of crop insurance policies, transactions for buying inputs and transfer of money between farmers, digital platforms that can determine the mandis prices for food grains, accessibility for rental services for warehouses, equipment specifically needed by small and marginal farmers. In other words, we can say that agricultural productivity has increased gradually over the period, the use of digital platforms has made more convenience, easier, reduction in transaction costs to farmers, benefiting the community, which will help in shaping future of rural economy.

Some of the policy initiatives include strengthening digital infrastructure so that accessibility of internet connectivity with affordable costs is ensured to farmers that will enable them to access digital platforms, advisory services, awareness of products and proper information about the market scenario. Digitization has also increased the depth of financial inclusion as it become easier and literate to rural population on awareness of affordable credit facilities, crop insurance, digital payments, innovative practices and support investment. Moreover, NABARD has been taken up initiatives on agri-startups and innovation hubs for promotion of research and development, incubation hubs, funding and initiating pilot projects before being implemented and executed on field, precision farming techniques as by-products of innovation and technological development in agriculture sector. Farmer training programs through Krishi Vigyan Kendras (KVKs) and extension services also enhance and improve digital literacy and adoption of modern technologies in agriculture sector. Encouragement of organic farming, water efficient irrigation practices for building resilience against climate change is another concern towards sustainable rural development. The participation of women population in self-help group, skill development trainings as well as promotion of women entrepreneurship is another incentives and agri-innovation through targeted schemes that will have a long-term socio-economic benefit to society and community at large in rural economy. The data and information of agricultural outputs, inputs and impact of digitization has validated from theoretical perspectives that there is a significant impact towards agricultural productivity with the integration and introduction of digitization in agriculture sector as well as facilitation of basic infrastructures on power supply, use of mobile phones by households and expansion in financial inclusion. However, the hypotheses need to be proof through experimentation and application of suitable econometric models to validate it with facts and data analysis.

Conclusion

Innovations in agriculture is not only about adoption of modern farming techniques alone, it requires a holistic approach towards the transformation of rural livelihoods in India. By integrating technological innovations and digitization, sustainability and inclusive practices, agriculture can emerge into a resilient and self-reliance sector that has long term impact towards food security and empowering the rural population. We can say that the future of rural India relies on empowering farmers including the women entrepreneur with proper training for skill development and enhancement, given the availability of infrastructures to facilitate such initiatives. Available data on agricultural outputs, inputs, infrastructures on digital platforms and supply of power, use of mobile phones, etc. has facilitated the Indian agriculture with agricultural productivity increases at a gradual phase manner. Incorporating the rising concerns on climate changes, population expansion and changing dimensions of market challenges the rural livelihoods, and the agricultural-innovation is one of the emerging transformative pathways towards rural sustainability and prosperity.

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