Chapter 6
Indian Agriculture Through the Decades: Returns and Efficiency of Resource Use

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Abstract In India's long journey of development and growth, agriculture has played a critical but constraining role. Associated critically with socio-political stability, India's agriculture still occupies large places in employment generation, food security and land use. Even with the self-sufficiency delivered by the Green Revolution (GR), Indian agriculture regularly deals with serious and often conflicting problems. Over time, as varied concerns challenged policy, agriculture also encountered new developments. The post-GR period was rich in insightful research and lively debates on the performances of agriculture, transitions in land use, regional disparities and assessments against other countries. In continuum and as a contribution to the discourse, this paper assimilates and presents a historical account of Indian agriculture, reinforced by an empirical study of contemporary times covering the base of GR in the Indo-Gangetic belt seeking to revisit the performance of Indian agriculture with updated perspectives.

Keywords Agricultural productivity · Farm income · Efficiency · Input elasticity

6.1 Background

In India's long journey of development, agriculture played a critical but constraining role. To start with, at the end of the second five-year plan, as planners became preoccupied with large industries, agriculture hit back on the success of the first one when droughts further tested dilution of their focus. Between the 1960s and early 1970s, trapped in severe food shortage, the nascent industrialization process drew relief from a public law passed in the USA (PL480) that allowed food shipments to India on rupee payment partly as a grant and partly as a long-term loan (Rakshit,

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2008, Hooda & Gulati, 2013) helping to build up vital food stocks and enabling deficit financing for industrialization. On the contrary, it discouraged investment in agriculture. The pressure on foreign policy created by this basic external dependence forced the government to try other policies and finally to discontinue the contract in 1971.

A life-saving technological advancement made in Mexico and later amplified in Manila came to the support of India when the Green Revolution (GR) was launched in the 1960s. Under the leadership of an esteemed scientist, M. S. Swaminathan, exotic hybrid seeds were tried out on Indian soils. Along with chemical fertilizers and pesticides, high-yielding variety (HYV) seeds constituted a bio-chemical package of inputs. Supported by necessary irrigation, legislated land reforms, price incentives, and credit and marketing privileges backed by public procurement at Minimum Support Price (MSP), GR saved the country from starvation but left its marks to be garnered and managed through history to this day.

While agriculture was meeting the food demands of Indian consumers who had started enjoying growing incomes, by and by, its significance also for the growth of the country's GDP gained visibility. While before GR, PL 480 was creating a market for industrial goods in urban India by depressing food prices, GR gradually steered the rural sector to emerge as a market for industrial products, thus empowering the growth of both the agriculture and manufacturing sectors.

Although India moved beyond food sufficiency and became a food exporter, the sustainability of agriculture, growth of agricultural GDP (GDPAG), management of food prices, and finally, the welfare of farmers appeared as continuous challenges. The government also had to address many historical repressions on agriculture with limited success.

By its own design, GR crafted regional and class disparities in the Indian economy (Frankel, 2006). The perfectly divisible bio-chemical inputs were size-neutral but not resource-neutral when only larger farmers had access to finances. The National Commission on Agriculture, 1976, had foreseen the coexistence of a large subsistence sector of small farmers with a progressive sector of large farmers who had acquired investible surplus (GOI, 1976). Already privileged with perennial rivers and irrigation, the north-west, along with a few deltaic basins of the east became the base of GR but they were only pockets of growth (Rao, 1983). While regional imbalances generated by GR have been well documented since the 1970s, loss of sustainability arising from intense input use soon added to the discourse.

Food price was proving to be a double-edged sword with contrary effects on producers and consumers (Mellor, 1966, Benjamin & Brandt, 2002). Moreover, the liberalization of 1991 made the price policy in consistent and the widening gap in incomes between agriculture and the rest of the economy become more conspicuous. At a time when the government's role was meant to shrink, a policy drawn from the years of food scarcity entitled farming to profuse budgetary support. Open procurement of rice and wheat, which is then produced in abundance, was expensive. Grain stocks to be maintained by the government became Voluminous, raising contradictions between the interests of farmers and the government's commitment to budgetary prudence and investment obligations. MSP was said to distort the market price that was expected to equate demand and supply. Over the 1980s, concerns also grew about the misuse and leakages of government funds from their legitimate uses.

The biased incentive to grow the beneficiary food crops rice and wheat across the country became untenable with sustanability. Even parts of the northern plains marked as the heart of GR are allured to grow rice in a departure from their traditional cropping pattern. The rotation of Kharif season rice with winter wheat began to degenerate their ecological balance even as traditional crops like millets, pulses and oilseeds lost share across the country. The food habits of the people (Baviskar, 2012) moved in tandem. In a changing paradigm, to rationalize cropping patterns away from food crops, the central government proposed wide ranging marketing reforms in which private and corporate sectors, especially the food processors, could join as buyers. Such changes in long-prevailing and adapted systems of infrastructure and skills are not politically easy to implement in federal India, where agriculture is a State subject under the Constitution.

In a new development, natural disasters became more evident, justifying fears of climate change (CC) raised by scientists at the theoretical level. An open-air activity, agriculture began to cope with serious rainfall anomalies in monsoon-dependent India. As CC portends to be a hard test on agricultural systems of the world (Del Buono, 2021), the urgency to adapt to more sustainable and climate-resilient forms grew. Post-2010, geo-political relations, growing inter-country dependencies, WTO agreements on fair trade and wars elsewhere encroached upon the economics of Indian agriculture and even revived food insecurity threats. The Russia-Ukraine war compromised India's access to edible oils and fertilizer. Trade itself became insecure in the conflict-ridden high seas. Timely trade negotiation, monitoring of the weather and production outlook, continual planning and management of surplus are now policy imperatives.

A move away from an exclusive focus on consumer interest was manifest when India added 'Farmers Welfare' to the name of the agriculture ministry in the year 2015 (15th August), making household earning from agriculture a major policy target. Another outstanding transformation in the early days of the new century was the entry of information and communication technology (ICT) into the vast and scattered rural economy. The ICT revolution raised hopes of bringing the rural economy to the mainstream and bridging the gulf between farmers and other members of agricultural value chains without excessive intermediation of powerful third-party agents (Ghosh et al., 2020). Computerization can aid fair efficient marketing with information dissemination. Price discovery, monitoring of practices, direct payments of public benefits, recording of agrarian structure, access to technology and advancement of institutional credit are likely to be beneficial.

The objectives of agricultural policy in contemporary times are broader than ever before, blending national food security with greater farm incomes even as the sector itself diversifies. Backed by an empirical assessment of contemporary times, this chapter is a review of the progress and broadenings of India's agriculture, taking up from the pre-GR days delving through the problems, achievements and left-overs of GR and focusing in particular on the post-GR period to trace the performance of India's agriculture and its various dimensions with a perspective departing from earlier studies only to capture current concerns. The discourse has two components. In the first part, the problems that Indian agriculture inherited from earlier regimes are discussed based mostly on a broad review of literature on agriculture that often focused on the inter-relations among environment, production and social and cultural features (Thorner, 1976). The second part is confined to contemporary India with a regional perspective on Indo-Gangetic plains (IGP) to find out the relative performances of the production, value added, inputs used and efficiency of input use also trying to explain the performance with empirical data analysis.

6.2 Indian Agriculture Over the Years: Performance, Challenges and the Transition

Challenges have accompanied Indian agriculture's long journey from the days of distressful food crises to the times of abundance in a dynamic and uncertain world. Problems either persisted in unchanged or mutated forms or gave way to new ones. Before stepping into the muddy track of Indian agriculture, it may be worth having a broad glimpse at the achievements.

6.2.1 Progress of Agriculture Under the Green Revolution

At the dawn of independence, Indian farmers were not only poor but also thought to be illiterate, superstitious (Haydock et al., 2021) and static in practice. The apprehension about their resistance to GR, however, proved unfounded as successful demonstrations by lead farmers and government encouragement led to widespread adoption of the new farm technology. The irrationality of farmers also proved to be an oversimplification when responses to incentives (Krishna, 1963) brought increasing area under the new seeds at a time when food prices were rising. A public extension system with field workers helped the technology to reach the fields.

GR undoubtedly served in tiding over India's food crisis, but even in the 1950 and 1960s, driven by acreage and irrigation expansion, the gross cropped area (GCA) had been rising fast (Fig. 6.1). Irrigation was a historical legacy from pre-colonial times. The colonial government applied the evolving engineering technology to build dams on the snow-fed Himalayan rivers, the Ganga and the Indus. In South India, local rulers managed rivers that were not perennial. GR replaced land and labour as sources of growth by land-augmenting bio-chemical inputs and, to a lesser extent, by labour-substituting machinery (Rao, 1983).

Between 1951 and 2020, India's population nearly quadrupled (Table 6.1). The annual growth rate tapered down from a high of 2.15% from 1951 to 1991 to 1.6% per year from 1991 to 2020. Although the figures for the 2020s are estimates, the latest Census being awaited, India's population is reaching saturation. Crop production,

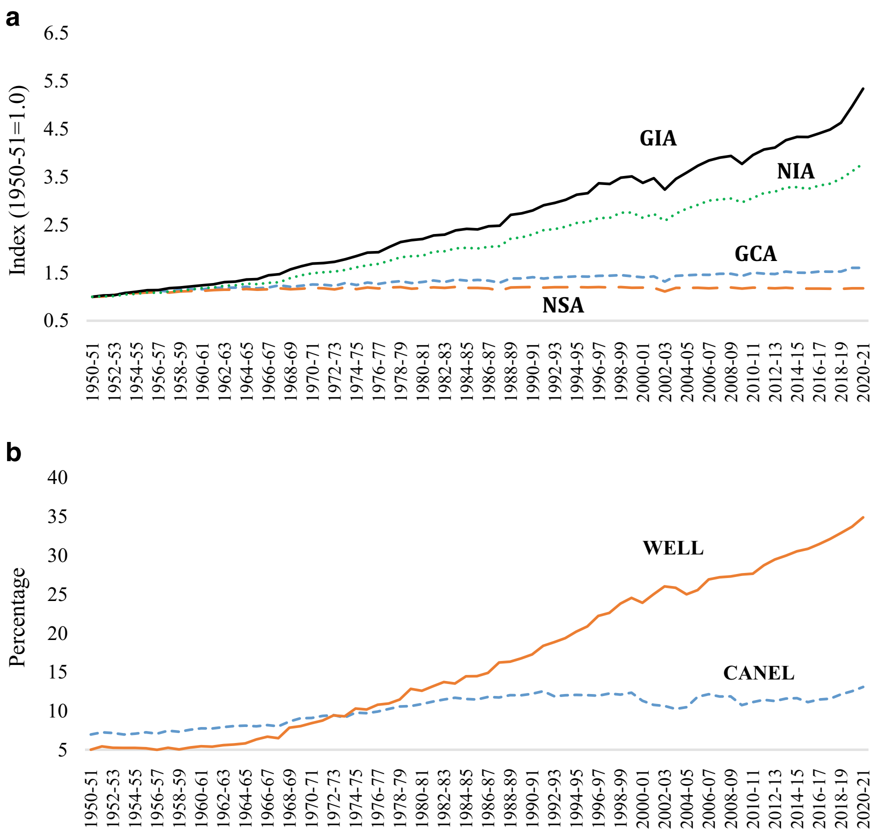


Fig. 6.1 **a** Land use in Indian agriculture from 1950–51. **b** Irrigation by source in Indian agriculture from 1950–51

too, rose, though constrained by limited land area (NSA) that stagnated at around 140 million hectares in recent decades. The initial land expansion came at the cost of forests, but from the 1990s, urbanization, housing, environment and infrastructure, especially highways, became contenders with agriculture for land. Fortunately, a consistent increase in cropping intensity (CI) in both periods kept GCA moving as expanding irrigation and short-duration crops (HYV) enabled multiple cropping of land. GCA reached 211 million hectares in 2020, compared to 132 million hectares in 1951.

From a mere 17% in 1950–51, irrigation intensity doubled by 1990–91 (Table 6.1). Though dwindling in drought years like 1987–88, 2002–03, 2009–10 and 2015–16, the expansion of GIA by 2020–21 in the face of a largely stable NSA was remarkable even as structurally, irrigation shifted sharply from surface to groundwater (Fig. 6.1a and b). Wells took over canals in irrigated acreage in 1973–74. By 2020–21 canals accounted only for 13% of NIA. Dams have since been rather discredited for failing to redirect natural flows of water (Ghosh et al., 2016). Nevertheless, water stored

Table 6.1 Transitions in Indian agriculture 1950–51 to 2020–21

Year	Population	Area (GCA)	Farm size	Fertilizer	GDPAG	Cropping intensity	Net irrigation	Rice and wheat share in GCA
	Million	Million hectare	Hectare	Kg./ Hectare	Rs.'000 / Hectare	%		
1950–51	361.2	131.9	2.96	0.5	23.49	111.1	17.1	31.1
1960–61	439.2	152.8	2.60	1.9	27.67	114.7	18.3	30.8
1970–71	548.2	165.8	2.28	13.1	32.35	117.7	23.0	33.6
1980–81	683.3	172.6	1.84	32.0	36.97	123.1	28.8	36.2
1990–91	846.4	185.7	1.55	67.5	50.58	130.0	34.0	36.0
2000–01	1028.7	185.3	1.33	90.1	67.74	131.1	41.1	38.1
2010–11	1210.8	198.1	1.15	141.9	87.22	140.1	45.1	37.2
2020–21	1347.1	211.4	1.08*	153.9	110.81	151.1	53.1	36.4
CAGR%	1.93	0.68	–1.54	8.53	2.24	0.44	1.63	0.23

Source DES (Website), MoA&FW (Website), Census of India (Website), DEA (2023). Population figures are for 1951 to 2011 from decennial Census of India but for 2020–21 figure is Census estimate. * India's latest farm-size figure in 2015–16

in reservoirs is monitored keenly for farming. Depletion of live storage in a major dam is an alert for water scarcity, and pressure on its capacity forces sudden release, which creates upstream or downstream floods. Groundwater irrigation, too, is not without its costs. It is blamed for water-table recession, land subsidence, inequity and electricity consumption. A conjunctive use drawing advantage of groundwater enriched by seepage in synergy with power generated at dams is recommended (Dhawan, 1988). Indian agriculture before GR hardly consumed chemical fertilizer, but growing phenomenally, it became the prime source of success. Despite the rapid intensification in the 1980s and 1990s, the paucity of its intake compared to countries like China and the USA was blamed for the relatively low crop yield rates (Table 6.2). By 2000, India, however, surpassed other countries in fertilizer consumption per unit NSA.

Staple cereals, rice and wheat together gained a share in the strained GCA up to 38% in 2001 (Table 6.1), while millets and pulses lost area. The contrast reflected the selective success of seed technology and all the biased government support for 'food' as perceived (Fig. 6.2a). Because of ecological adversities of mono-cropping and shortage of nourishing crops, crop diversification (Sivaraman, 2023) was promoted, perhaps as a result of which rice and wheat together lost share from 2000–01. Though rice, jowar and lentils failed to catch up to the world's best, physical productivity increased for all study crops, not excluding pulses and millets that lost acreage (Fig. 6.2b).

Table 6.2 Country wise crop productivity (tones/hectare) and Fertilizer intake (Kg./Hectare)

		1961	1970	1980	1990	2000	2010	2020
Rice	India	1.5	1.7	2.0	2.6	2.9	3.4	4.1
	China	–	–	–	–	6.3	6.5	7.0
	USA	3.8	5.2	4.9	6.2	7.0	7.5	8.5
Wheat	India	8.5	1.2	1.4	2.1	2.8	2.8	3.4
	China	–	–	–	–	3.7	4.7	5.7
	USA	1.6	2.1	2.3	2.7	2.8	3.1	3.3
Jowar	India	0.4	0.5	0.7	0.8	0.8	0.9	1.0
	China	–	–	–	–	2.9	4.4	8.1
	USA	2.7	3.1	2.9	4.0	3.8	4.5	4.6
Lentil	India	0.5	0.5	0.4	0.6	0.7	0.7	0.8
	China	–	–	–	–	1.2	2.0	2.5
	USA	0.7	1.0	1.1	1.0	1.6	1.5	1.6
Rapeseed Mustard	India*	0.4	0.6	0.6	0.9	0.9	1.2	1.5
	China	–	–	–	–	0.6	0.7	0.8
	USA	0.95	1.0	0.94	0.95	0.95	0.97	1,0
Fertilizer consumption of Agricultural Land (NSA)	India	2.6	–	–	53.6	–	–	181.7
	China	NA	–	–	69.3	–	–	85.9
	USA	16.7	–	–	42.7	–	–	51.7

Source FAOSTAT (Website), DES (Website)

The crop yield gains, however, did not come without cost. While not all costs are quantifiable, financial costs in terms of input costs can be subtracted to measure the income generated from farming activity. India's national income measured by GDP at constant price picked up speed in the 1970s, more remarkably in 1991–2010, falling in 2021, the year of pandemic but the slow-moving GDPAG barely remained above the plateauing population (Fig. 6.3). GDPAG per hectare at 2011–12 price reached Rs. 111 thousand in 2020–21 growing at 2.24% annually when real GDP per hectare grew at 4.07%.

6.2.2 Waking up to Post-GR Problems

When GR, antibiotics and other medical technologies defeated the Malthusian predicament, the rapid march of population in the twentieth century did not economically help India's farm sector that was languishing in poverty since independence. An inefficient feudal framework, further reinforced by the British land revenue system, generated highly unequal rural power equations with unproductive intermediaries in institutions that operated in complex ways. Independent India's government had to

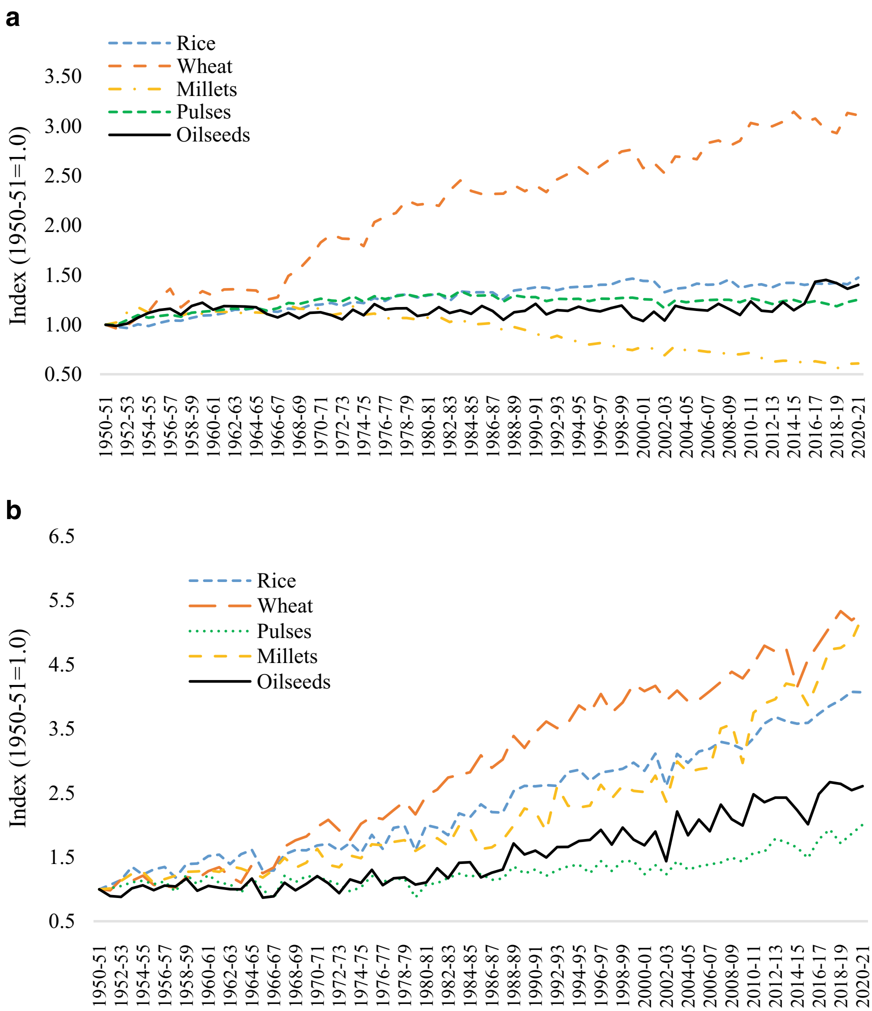


Fig. 6.2 **a** Area under major crops in India. **b** Crop yield progress

legislate land reform measures like abolition of the established zamindary system, land ceiling and their distribution of attached surplus land to prevent land holdings from becoming too large. Regulation of rent and restraints on tenant eviction aimed to empower farmers to take risk.

Market imperfections, commonly described by the 'interlocking' of markets, entitled powerful entities to appear before the farmer in different markets that were entangled without distinction (Bhaduri, 1984). A landed rich farmer would not just lease out land but double up as a trader to dictate the crops to be grown and become suppliers of inputs. Appearing as money lenders charging high rates of interest on capital, they often entrapped farmers in debt. In cases of extreme default, by attaching

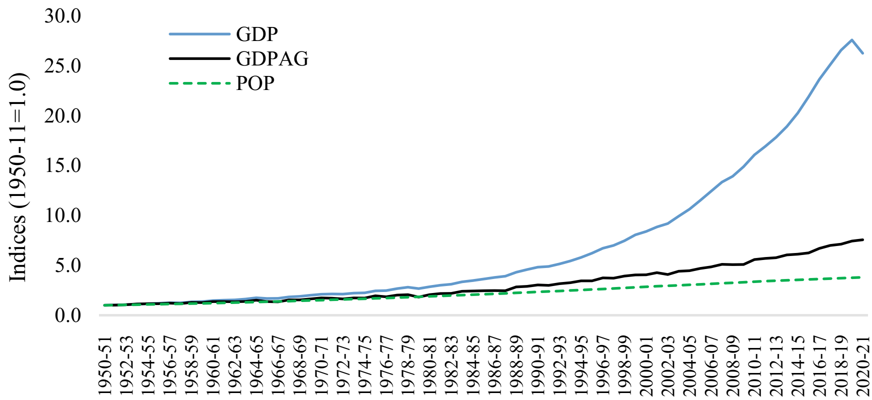


Fig. 6.3 Agricultural growth in India

all of their land they reduced marginal holders to join the ranks of farm labour class. On the contrary many 'absentee landlord would not even cultivate land'.

The small and continuously diminishing average farm size impeded mechanization and commercialization yielding little product surplus for sale. Large sections of peasants with small (up to 2 hectares) or marginal (up to 1 hectare) holdings lingered at subsistence levels though they had utilized family labour to their advantage (Tripp, 2006) during GR while banking support and subsidies helped them adopt the bio-chemical technology. Due to cultural inhibitions to manual work (Waite, 2005), large holders resorted to hiring labour and further to purchasing machines in response to rising wages. However, as population grew, income generation capacity of agriculture was stunted by the fragmentation of farms reinforced by a dysfunctional land market abetted by the cultural value attached to holding land (Ghatak & Roy, 2007). Still grappling with an over 86% share of small and vulnerable farms, India is exploring ways to develop small industries, accommodate a large informal sector and generate off-farm rural employment opportunities.

Indian agriculture depends strongly on monsoon which has always been errant. River valley projects contributed to canal irrigation and flood control services. They also generated electricity that powered well irrigation. Although, the independent government of India vastly expanded the infrastructure, irrigation itself depends on rainfall and its expansion has limits. Many agro-climatic regions have to subsist in water scarcity. Expansion of irrigation had to be accompanied by effective water management. Soil organic content was degraded as chemicals leached into the water and air. Relentless use of bio-chemical inputs needed restraint as sustainability became a component of agricultural policy objective.

Towards a more competitive product market, in colonial times, the Agriculture Produce Marketing Committee (APMC) was instituted with auctions where traders were licensed. To entitle farmers to fair prices and escape unscrupulous agents, this legislation was reinforced by the independent government. To curb distress sales a dual market was created where the government conducted with open procurement at minimum support prices. Although MSP was not a legal commitment, administratively it assured farmers of sale at remunerative prices and also influenced the price in the open market. To free farmers from the clutches of local exploitative money lenders, the new government of the 1950s also regulated money lending while expanding the banking network across rural India. Widely nationalizing banks in 1969 and committing them to a priority loan-share to farmers were further steps. A tiered cooperative credit structure was constituted going down to the grassroot level with their apex body NABARD formed in 1982 for regulation. Subsidies on food and inputs were accommodated in public budgets. Machines were made cheaper with import policy. Economic, administrative and judicial means were deployed to make irrigation projects, their command area development and water distribution efficient. Deficiencies in the measures were widely and critically researched.

6.2.3 Misgivings that Lingered

Misgivings shrouded GR from the start but redressals were incomplete. Dilution of the objectives of agricultural Census for designing land ceiling, tolerance of oral tenancy, false titling of land (benami) and other evasive strategies of land owners limited the success of land reforms. Described as kulaks (Singh, 1987) a class of capitalist farmers who were progressive enough to drive the GR emerged but by and large the legislations could hardly battle the entrenchment of caste and class relations with land ownership. Prevalence of informal tenancy permitted evasion of tenurial laws. Even the progressiveness of endowed commercial farmers was questioned (Nair, 1983). Nair attributed the differences in input use and growth rate evidenced between Bihar and Punjab despite their similar soils and land laws to the risky ambience in eastern India leading to the small holder dominance and choice of share-cropping practices. Soon the same land laws began obstructing the formation of land markets and inhibited even legal leasing of land that could have replaced disinterested landlords by enthusiastically practicing tenants.

The number of smaller farmers swelled with land fragmentation. Being historically privileged with irrigation (Khushro, 1964) and family labour, they were argued to be more productive as evident from FMS data of the time. Evidences even suggested an inverse relation of productivity with farm size raising one of the liveliest and sustained historical debates (Sen, 1964). Over time, as population grew the average farm size came down in size and viability (Table 6.1). Household members had to resort to off-farm economic activities to supplement farm incomes and even migrate to distant states to make a living and survive. Migration could be theoretically an equilibrating process signalling progress (Todaro & Smith, 2020) but the rural migration from eastern villages is said to be a distress driven ‘push’ the weakness of which was glaringly exposed by the pandemic crisis marked by ‘reverse migration’ (Naregal, 2021). Creating local employment began to be seen as a way to prevent distress migration (Borah, 2022).

Burdened with prudential norms formal bankers soon began showing reluctance to lend to a risky sector. Rural credit repeatedly led to defaults and faced setbacks especially following droughts when distress of farmers compelled loan waivers by the governments. Despite a crop insurance scheme operating since 1999 to enable banks continue with lending, informal money lenders, found to be timelier and simpler in procedures, persisted. Market regulations too reached their own limits generating a kind of monopsony of local licensed traders who remained backward in methods (Ghosh, 2013), barring entry of more efficient new agents and depriving farmers of new markets, alternative products and higher prices. The MSP was seen to hinder market reform and equity. The market remained highly fragmented by various formal and informal barriers to grain flows within the country and in fact, advocates of globalization claimed that farmers were 'dis-protected' in the global market (Gulati, 2009). To take care of farmer's income and equity, procurement was extended to crops beyond rice and wheat and MSP was announced for 22 crops committing 50% profit over cost and a price stabilization fund was formed mainly for pulses. But the benefits continue to bypass small and subsistence peasants with little surplus.

A model marketing act was circulated in 2004. Largely a failure with states differing widely in their reactions, the event did set in motion a slow progress in the opening up of markets to private operators, emergence of innovative market channels and formation of farmers' collectives (Ghosh, 2013). In 2021 (November) the Union government under a majority rule took Constitutional advantage to pass but soon withdraw three market reform laws[1]even while a clamour for legalized MSP arose. Amendments to an established system tied to livelihood of large sections obviously proves politically difficult.

6.2.4 Contemporary Challenges and Paradoxes

Independence found Indian agriculture constrained by backwardness, technological deficiencies, climatic debacles, poor institutions and the miserable poverty of small farmers. Low productivity translating to low production and national food insecurity in a land-scarce nation was historically the primary problem addressed. Achievement in the GR and in post-GR times can best be summarized by greater land utilization from fast growth of CI and yield from a hectare of cropped acreage accompanying expanding irrigation and use of fertilizer and HYV seeds. Yet, GR exacted higher costs not always quantified. Certain external effects and developments also turned the situation.

[1] Agreement on Price Assurance and Farm (Empowerment and Protection) Services Act 2020, Produce Trade and Commerce (Promotion and Facilitation) Act 2020 and the Essential Commodities (Amendment) Act 2020.

6.2.5 Climate Change

Climate change (CC) is probably the most outstanding intrusion into policy space in recent times. Emissions and rise of global temperatures, as recorded by the Stevenson screen, strengthened by subsequent instrumentation, and a meeting at Rio in 1992, culminated in successive negotiations and commitments to limit emissions (Ghosh, 2011). Severe and extreme weather anomalies and events like heat waves, storms, droughts or excessive rainfall with little predictability could arguably result in CC. Harm already inflicted by past emissions is not easy to reverse. Indian agriculture has always depended on a capricious monsoon, but as its anomalies became a regular feature, policy had to impart climate resilience to agriculture, an activity most exposed to nature.

Analysis of meteorological data (IMD, Website) suggests that monsoon is regionally diverse in pattern and may be diminishing (IMD, Website) with rainfall deficits increasing (Pandey & Sengupta, 2018) in some places. The government has responded with legislated disaster management, climate-sensitive research and information dissemination. Farmers, known to be adaptive to nature, may also be adjusting practices to the transition (Ghosh et al., 2022). Drought and flood management by continually forecasted and monitored, weather and production.

6.2.6 Information and Communication

Poor communication in dispersed Indian villages traditionally inhibited the flow of goods, money and information, leading to frequent food scarcity. India's development policy today lays great emphasis on infrastructure creation. While the farm population stands to benefit from physical connectivity and from the employment generated by construction, it is not enough. Data itself has become a fuel for powering the economy. The most outstanding development is brought by the information and communication technology (ICT) that started to invade the rural economy in the early years of the current century. The average farmer, as part of the rural population, is far more educated than in GR days and ICT with its multiple language outreach overcomes much of the limitations faced by farmers in connecting to technology and the market.

Extension, which had begun floundering after GR, switched to an online and more interactive mode for problem-solving, information sharing and early warning as both extension and crop insurance became more privatized. ICT has made money transfers simpler and safer. At the root of this revolution lies the authentication by JAM, which involves a bank account (JanDhan), Unique identity (Aadhar) and mobile connectivity. Direct-benefit transfers from government (DBT) are making subsidization simpler and more secure from malpractices. In a token measure of income redistribution, a DBT known as PM-Kisan (PIB, 2023) credits the accounts of small farmers. Credit allows farmers to access inputs and better technology in time. It has always been important, but in its long evolutionary history, farm credit is revolutionized by the issue of the Kisan credit card (KCC). Further strengthening and simplification by computerization of land records (Samantara, 2010). ICT still holds immense potential for agriculture.

6.2.7 Farmer's Income

A promise of doubling the farmer's income heralded a shift in focus from production to producer income. Large sections of Indian workers who depend on agriculture in some way include landed farmers, lessors of cultivable land, hired farm labourers, unpaid workers of family farms, suppliers of animal services, water and machine power. Expenses made for production accrue either to them or flow out to manufacturers of material inputs in other sectors. The price rise of material inputs constrains farmers' income. As the importance of supplementary off-farm incomes grew, the government placed emphasis on agro-processing and many welfare measures, reforms in MSP targeted towards a wider range of crops and reducing corruption with innovative methods. PM-Kisan was an additional pay-out over farmers' income to mitigate the hardship of farmers.

6.3 Contemporary Scene

We now come to focus on the contemporary period, i.e., the new century and millennium, Indo-Gangetic belt (IGB), the prime beneficiary region from GR and major food crops grown in IGB states. The data covers 11 states in the IGB over a time period of 16 years and includes 12 crops. Based on climate, soils, river basin projects and history, three broad sub-regions (Table 6.3) are also delineated from among the select states in the IGB: Eastern (E), Central (C) and North Western (NW). Data for the analysis are taken from official sources. MOA&FW provide data on crop yield, area and prices (wholesale price) as well as total irrigation by sources are collected from DES, Website and inputs and costs from cost of cultivation (COC) since DES does not report cost data. However, from the sample surveys, COC is the only credible source in the public domain on inputs in values and physical measures (for many inputs) and cost per hectare. For each state, a number of food crops constituting at least 70% of its total GCA and 87% in foodgrain and oilseed areas are considered in the study. Their share exceeds 85% of the food crop area in all the regions, though in some diversified states such as Gujarat and Rajasthan, horticulture and cash crops have a substantial share in GCA.

Total state-level use of individual inputs, composite input cost and the composite output price are all derived as averages across only select crops (from COC) weighted by crop acreages in the states (from DES). We sum up the value of all crops (price (P) x yield (Y) x area(A)) and divide this total by the sum of the area under all these crops to obtain the value of crops (VO) in Rs per hectare. From this we subtract

Table 6.3 Study regions and study crop share in Area (%)

Regions	State name	Crop name	GCA	Foodgrain and oilseed area
Eastern Region (ER)	Bihar (BH)	Maize, Rapeseed, Paddy, Wheat, Gram	81.2	91.0
	Jharkhand (JH)	Maize, Paddy, Wheat	86.6	86.3
	Orissa (OD)	Paddy, Arhar, Moong, Urad	76.1	85.8
	West Bengal (WB)	Rapeseed, Paddy	62.0	84.8
	State total		71.6	86.3
Central Region (CR)	Chhattisgarh (CH)	Maize, Paddy, Wheat, Gram, Urad, Soybean	78.0	82.1
	Madhya Pradesh (MP)	Jowar, Maize, Rapeseed, Paddy, Wheat, Arhar, Gram, Urad, Soybean	81.1	88.5
	Uttar Pradesh (UP)	Bajra, Maize, Rapeseed, Paddy, Wheat, Arhar, Gram, Urad	73.6	90.6
	State total		77.2	88.9
North Western Region (NWR)	Gujarat (GJ)	Bajra, Groundnut, Maize, Rapeseed, Paddy, Wheat, Arhar	42.4	72.2
	Haryana (HY)	Bajra, Rapeseed, Paddy, Wheat, Gram	64.7	96.7
	Punjab (PJ)	Paddy, Wheat	80.5	96.5
	Rajasthan (RJ)	Bajra, Jowar, Maize, Rapeseed, Wheat, Gram, Moong, Urad, Soybean	65.1	84.4
	State total		62.0	85.2
All region			70.2	86.9

the sum of all material cost (MC) across the study crops in Rs/hectare to obtain the value added (VA) in Rs/hectare in the state farming. VA includes farm profit and remuneration from farm, animal and machine labour. All the data are expressed at per-hectare level of study crops, and all value measures are further divided by CPI for an agricultural labourer (CPIAL) of the state and year for temporal comparability to control for the effect of inflation. The assessment of performance is made tracking land use, the use of inputs, the output and the efficiency. Simple graphs are major methods of tracking, but regression models with Stochastic Frontier Analysis (SFA) and efficiency are also part of the methodology.

Conceptually,

$$\mathrm{VA} = \mathrm{VO} - \mathrm{MC} \tag{1a}$$

$$\mathrm{VO} = \mathrm{P} \times \mathrm{A} \times \mathrm{Y} \tag{1b}$$

Table 6.4 Mean of the variables in the equation (Sample Average)

	Unit	Eastern region	Central region	North western region	State average
VA	Rs'000./ Hectare	28.4	23.7	39	30.3
Fertilizer	Kg./Hectare	103.3	105.8	145.9	118.3
Irrigation	Ratio	0.6	0.6	0.7	0.6
Tractor purchase	unit/'000 Hectare	2.9	2.6	2.9	2.8
Rent	Rs.'000/ Hectare	8.9	9.4	13.5	10.6
Human Labour	Hours/ Hectare	809.7	449.6	386.3	548.5
Reservoir volume	BCM	3.7	8.5	6.4	6.2
Monsoon rainfall;	centimeter	118	1065	48	906
Farm Size	Hectare	0.8	1.3	2.8	1.6
Credit	Rs. Cr/'000 Hectare	2.0	1.4	3.5	2.3

where Material Cost (MC) is the sum of costs of material inputs, which includes Fertilizer costs, Manure costs, Owned machine labour costs, Seed costs, Insecticides costs and Owned animal labour costs. By excluding from the real value of output (VO), the component that moves away to the industrial sector as material cost (MC), VA is derived as the residual output that accrues as incomes to the agents who serve agriculture (Eqs. 1). Under the contemporary priorities, the performance of agriculture would be better represented by VA than the production and farmer's profit. Although the VA is fairly low at Rs. 30 thousand on average, not surprisingly, it is highest in the GR beneficiary NWR at Rs. 39 thousand, followed closely by ER (Table 6.4).

6.3.1 *Explaining the Productivity*

The performance of agriculture is believed to be an outcome of many factors like nature-ordained soil fertility and climate, the use of material inputs as decided by supervising farmers, labour hired or from family members, past investments made by farming agents on assets like machines for cultivation and irrigation services from public and private assets and above all the efficiency of use of all inputs and technology that reflects the managerial competence. Despite falling behind in rainfall, water in reservoir storage and labour use, NWR, with a larger average farm size (3.8

hectares), has a lead in outcome as well as inputs. Over time, however, things have not been static.

Technological relations between inputs and output can be comprehended with production functions analysis (PFA) of empirical data. In agriculture PFA is conducted using linear, log-linear, Cobb–Douglas, quadratic and Translog functions in structural form for years but price-based reduced form and use of instrumental variables (IV) help avoid endogeneity in an equilibrating market (Heady, 1952, 1957, Nathan, 1971, Narayana et al., 1991, Ghosh & Neogi, 1995). Among examples is a predicted rise in demand for farm machinery, with farm-level strawberry data analysis showing that machines complemented labour and were highly productive.

Multiplicatively, production function is given by Eq. 2a.

$$y_i = f(x_i; \beta)e^{(v_i)}[i = 1, 2, \ldots..n] \tag{2a}$$

Or in explicit firm production is modelled as

$$\mathrm{Log\ Y} = \mathrm{a_0} + \Sigma \mathrm{a_1}(\mathrm{Log\ X_i}) + (1/2)\Sigma \mathrm{a_2}(\mathrm{Log\ X_i})\left(\mathrm{Log\ X_j}\right) + \mathrm{u_{it}} \tag{2b}$$

where the dependent variable is Y and Xi are the inputs in a non-linear relation and Y is a stochastic variable While for X_i non-stochasticity in some cases doubtful, instrumetal variable are use overcome endogeneity. The term X_iX_i is the interaction term between the same inputs when $i = j$. The squared input variable will expectedly suggest a negative coefficient depicting the adversity of excess input use. Between two different inputs, the interaction term can carry a positive (complementarity) or a negative (substitution) coefficient. VA is modelled with Eq. 2b using several intuitively plausible explanatory variables. Pooled data gives observations that are subjected to panel data regression, pooled (POLS), random effect (RE) and fixed effect (FE).

6.3.2 Stochastic Frontier Models and Measuring Inefficiency

In a seminal study, Battese and Coelli (1992) set a wave of empirical research to estimate the possible frontier of production possibility and measure the inefficiency of firms, both of which exercises would be useful for policymakers in adjudging, monitoring and comparing production performances in a sector and identifying the factors that can be modulated to improve the performances holistically. Voluminous work (Aigner et al., 1977, Battese & Coelli, 1992, 1995, Jondrow et al., 1982, Kumbhakar & Lovel, 2000, Greene, 2005, Ghosh & Neogi, 1995, Neogi & Ghosh, 1995; Neogi et al., 2014) make up the literature on stochastic function model with efficiency measurement. Results on farm size, mechanization, input use, crop choice and biodiversity (Larsen & McComb, 2021, MacDonald et al., 2014, Muyanga & Jayne, 2019, Noack & Larsen, 2019, Geiger et al., 2010, Hautier et al., 2011) flowed from the limited application of the method to agriculture.

The basic premise behind the approach is that the efficiency of practices under the given natural conditions can account for production differences between similar units that use the same inputs. Stochastic Production Frontier (SPF) is the means to measure the maximum output possible with the given inputs in an ideal case, though in reality, the producing unit may not be perfectly efficient, and the observed output will fall short of the frontier. Further, the unit's inefficiency measured by the shortfall can be modelled as a component of the residual whose other part is the usual random iid that can be both positive and negative. Ideally, a producer can be assumed to exert effort to attain complete efficiency and thereby reach the frontier output (Batteste et al., 1989; Battese & Coelli, 1992, Coeli et al., 2003).

The conventional representations of SPF function multiplicatively and logarithmically are respectively,

$$y_i = f(x_i; \beta)e^{(v_i - \mathrm{u})}[i = 1, 2, \ldots..n] \tag{3a}$$

and

$$\mathrm{Log\ Y} = \mathrm{a_0} + \Sigma \mathrm{a_1}(\mathrm{Log\ X_i}) + (1/2)\ \Sigma \mathrm{a_2}(\mathrm{Log\ X_i})\left(\mathrm{Log\ X_j}\right) + \mathrm{v_{it}} - \mathrm{u_{it}} \tag{3b}$$

where $\mathrm{v_{it}}$ is random iid following N(0, σ2v), and is independent of $\mathrm{u_{it}}$ while $\mathrm{u_{it}}$, a non-negative random variable independently distributed N($\mathrm{m_{it}}$, σ2u) truncated at zero is assumed to account for the technical inefficiency in production. The technical efficiency is given by Eq. (6.4)

$$TE = \frac{Y_i}{Y_i^*} = \frac{f(x_i; \beta)e^{(V_i - U_i)}}{f(x_i; \beta)e^{(V_i)}} = e^{-U_i} \tag{6.4}$$

Estimation in SFA using maximum likelihood (ML) has been developed in the literature (Kumbhakar, 2000, Battese & Coelli, 1992, Greene, 2005) with varying approaches. To disentangle time-varying inefficiency from unit-specific time-invariant unobserved heterogeneity, Greene's method, termed the 'True time-varying model', is used employing panel data following 'Fixed effect' or 'Random effect' depending on the visualization of the case and the assumptions on the unobserved unit-specific heterogeneity. Specifications used in modelling are pooled Ordinary Least Square (POLS) and Radom effect (RE) are examined and their results presented.

The variation of efficiency or inefficiency is then explained with exogenous variables. Taking $\mathrm{u_i}$ as a function of relevant variables and an intercept term the equation is

$$u_i \sim N^+(\mu_i, \sigma_u^2)$$

$$\mu_i = z_i\prime\varphi$$

where $u_i$is a realization from a truncated (or half) normal random variable, $\mathbf{z}i$is a vector of exogenous variables (including a constant term), and φ is the vector of unknown parameters to be estimated.

Such influences may include the average farm size decided by demography. Credit disbursal by the organized financial system measured by crop loan value deflated by CPIAL per hectare of GCA shaped by the country's financial system and government policy of crop insurance and subsidies can be another effect on efficiency. Infrastructural assets like roads could matter.

6.3.3 Model

In Indian agriculture, the exercise would be particularly relevant for policy-making to achieve aims like enhancing farmer incomes (DFI[2]), achieving regional balance, especially for the rain-fed eastern region (RADP[3]) and the emerging Central region, attaining sustainable development with resource use efficiency especially in the Western belt of Indo-Gangetic basin (IGB) and addressing farmers' welfare. With a broad dataset, the cross-section units can be comprehensively described by nature, policy and decision variables some of which are quantitative while others are more qualitative represented by dummy variables.

All analysis for inputs and outcomes is done at the per-hectare level with real values using methods PFA as well as SFA. The RE model with IV is preferred based on a Hausman test and to accommodate the dummy variables for characterization without treating the units as distinct with their fixed effects. The robustness of the model is indicated by the RE and POLS, producing largely comparable results with the same signs of the coefficients. Application of input j that is decision of the farmer is given by

$$X_{jst} = f\left(P_{jst},\ Z_{jst}\right)$$

where P is the relative price of input relative to composite crop price and Z is any other relevant variable, both variables being crop neutral.

[2] Government had constituted an Inter-Ministerial Committee in April 2016 to examine issues relating to 'Doubling of Farmers Income (DFI)' and recommended strategies to achieve the same. The final report in 14 volumes was submitted to the government in September 2018 suggesting various policies, reforms and programmes.

[3] Rainfed Area Development Programme (RADP) is launched in the year 2011–12 as a sub-scheme under Rashtriya Krishi VikasYojana (RKVY) for improving quality of life of farmers' especially, small and marginal farmers by offering a complete package of activities to maximize farm returns. RADP focuses on Integrated Farming System (IFS) for enhancing productivity and minimizing risks associated with climatic variabilities.

6.3.4 Variables

For each cross-section unit, a varying number (n) of crops (i) are covered depending on their dominant cropping pattern. Corrected for price rice VA for a state(s) is expressed as

$$VA_{st} = \frac{\frac{\sum_i P_{ist} Y_{ist} A_{ist}}{\sum A_{ist}} - \frac{\sum_{ist} MC_{ist}}{\sum A_{ist}}}{CPIAL_{st}} \tag{6.5}$$

Among natural explanatory variables is the land, which is measured by its productive power considering the three most dominant soil types of India, namely, alluvial (AVL), Black (BLK), and Red (RED), ranked in each state by their shares in the GCA to construct corresponding dummy variables. For example, if AVL ranks first in states, the dummy is AVL1 (AVL1 = 1 if it ranks first and zero otherwise).[2] The economic contribution of land depends on its location near a road, railway station, town, market or other facilities and other attributes like elevation or depression, rockiness, soil organic matter (SOM[4]) richness, proneness to waterlogging, etc. In the absence of such profound characterization in the data, rent on owned land (RENT) as given by COC is used as a proxy, assuming that the reported rent takes account of superiority over marginal land as classically postulated (Ricardo, 1963).

Climate is a natural attribute but is expected to be interactive with other water variables. Appearing as ratios of dams and irrigation variables in the model representing past investment in structures and equipment (motors, pumps) by public and private agents. Water supply for irrigation in the desired amount depends on the average storage in the reservoirs (RSV) in river basins in the respective sub-regions holding managed water from past natural rainfall. The river projects incur huge budgetary costs for administration. Irrigation facility helps to make use of the natural and stored water.

Soil fertility can be modulated by the use of chemical fertilizer whose application (FERT) is decided based on prices and constrained by working capital and water available. Fertilizer use, associated with target production, can ingrain endogeneity. Labour (LAB) used of both by family and attached labour (FLAB) and by casual labour (HLAB) can be seen as an endogenous decision too, depending on wage relative to crop price and available machine and other ingredients both exogenous to farmer's decision. Although farm implements like threshers, tillers and pumps also substitute for human labour, animals and ploughs, tractor remains the most dominant machine. It is acquired by a one-time large investment, but the practice of leasing machines has grown, crossing over local and district boundaries even to inter-state lending (Singh, 2017; Mehta et al., 2023). In the burgeoning machine service market, larger farmers are likely to invest primarily for their own use and small farmers to hire their extra capacity, but with long-term easy credit available,

[4] Soil organic matter is the fraction of the soil that consists of plant or animal tissue in various stages of breakdown (decomposition). Most of our productive agricultural soils have between 3 and 6% organic matter. Soil organic matter contributes to soil productivity in many different ways.

any reversal of the roles and emergence of a professional class of service providers is not improbable. Measured using two alternative specifications, as number of tractors sold (TRAC) and as cost of machine services (MACH), mechanization of farming (TMA, Website, COC) will be influenced by economics and farm size. Covering all machines (MACH) allows the state of income accrual and ownership to differ.

6.4 Contemporary Scene

Empirical evidence on the outcome and input of Indian agriculture are elicited from data from the reference period 2005–06 to 2020–21 in the three regions East/Northeast (ENE), Central (C) and North-Western (NW) region.

6.4.1 Land Use

As a total cropped area, which is net land area (NSA) times CI, grew, cropping patterns moved in different ways. Among the major field crops, rice gained area shares in E and NW but lost share in C. Cropping patterns moved away from pulses and oilseeds in region E, but wheat and millets (mostly maize) gained. C moved away from rice, millets and even pulses it was once known for. Also, strangely, wheat lost share in NW along with millets and oilseeds but moved towards pulses and rice. The most remarkable in improved cropping intensity was C (Fig. 6.4a), while NW recovered only in 2018–19 after a long slump. The laggardness of the East in land utilization can be attributed to the slow growth of irrigation intensity (Fig. 6.4b). Association between irrigation and cropping intensities seem clear with C winning the race in both and NW lying in slump between 2011 and 2018. Analogously, canal irrigation increased in tandem with reservoir storage in E but canals lost share in the other two regions.

As can be expected the average farm size decreased in the time period but the reduction was relatively low or even minimal in Haryana and West Bengal while farm size came down by 8% in Punjab, 22% in Madhya Pradesh and 19% in Rajasthan (Fig. 6.5).

Rainfall appears uneven in the study period but behaved dissimilarly (Fig. 6.6a). Temporally, all three regions encountered swings annually creating temporary crisis but giving space for reservoir storage while spatially, the trends did not necessarily merge. Reservoir levels increased in all regions It may be noted that higher levels in May augurs well for Kharif cultivation but actual impact would depend on the water management performance (Figs. 6.6b and 6.7).

Represented by the value-added per hectare, output from agriculture accruing as incomes in the sector grew fastest in E over the entire period. VA in region NW increased in sync with E till 2007–08 but C moved sower. Towards the end of sample period NW and C moved in sync but E was growing faster in VA (Fig. 6.8).

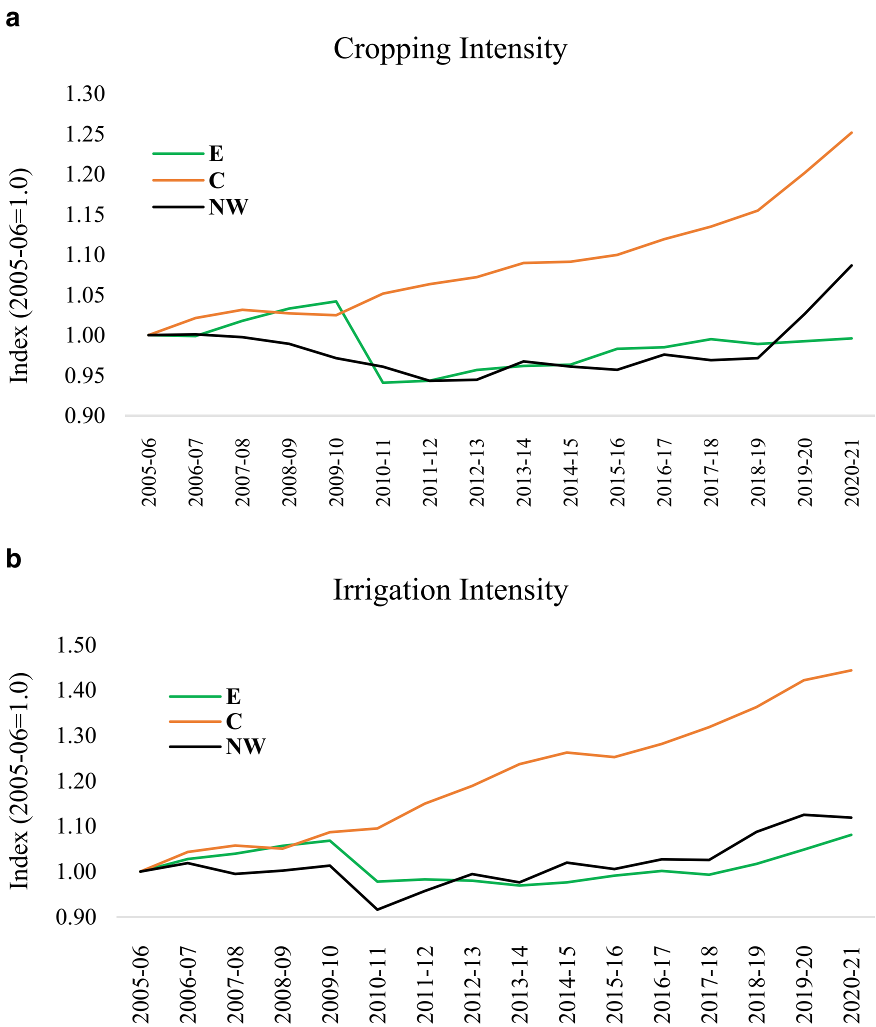
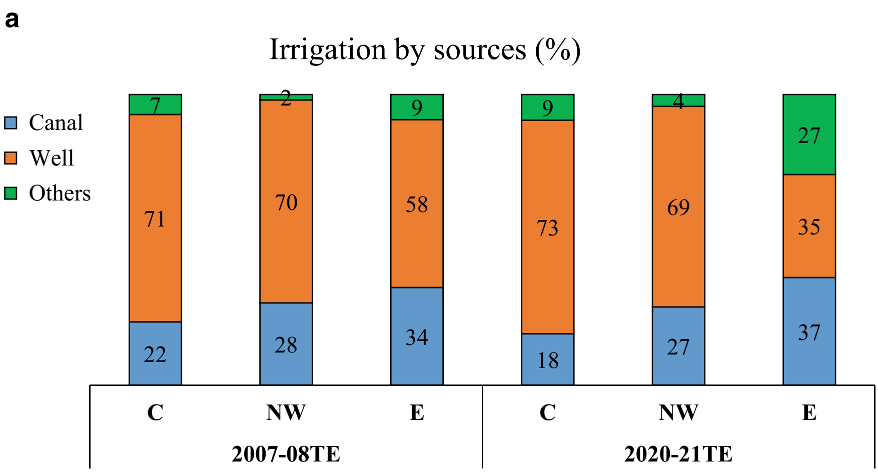


Fig. 6.4 Crops and irrigation

6.4.2 Input Use

Among the major input variables (Table 6.5) in physical units, fertilizer use increased by highest amounts and interestingly, while NW started with high intake and grew, the other regions tended to catch up as seen in the plots in logarithms in Fig. 6.8. Labour inputs came down in all three regions but remained highest in E. All three regions exhibited healthy growth in mechanization measured by machine services but moved conversely with labour use by both indicators (Fig. 6.9).



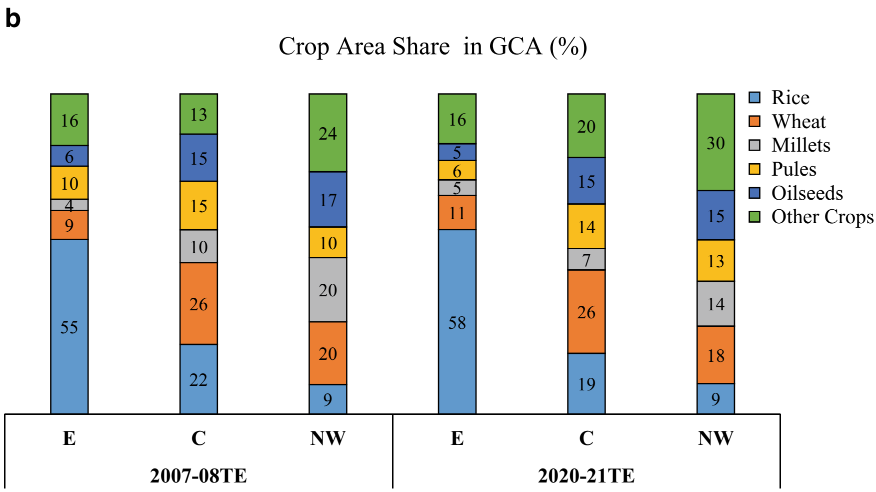


Fig. 6.4 (continued)

6.5 Productivity Analysis

Value added for the model, estimated using panel data with simple Pooled OLS and stochastic methods, brings out similar results. While the auxiliary equation with IV (Table 6.6) suggests that the price of fertilizer relative to the average crop price determines its use with a significant negative effect, working capital and irrigation facilities of all types available have positive effects. Fertilizer used as IV is an important contributor to VA, for which alluvial soil appeared as the dominant factor. Other useful attributes of land signified by the rent also emerge as statistically significant. Water, of course, shows a supportive role of higher average rainfall incidence and the

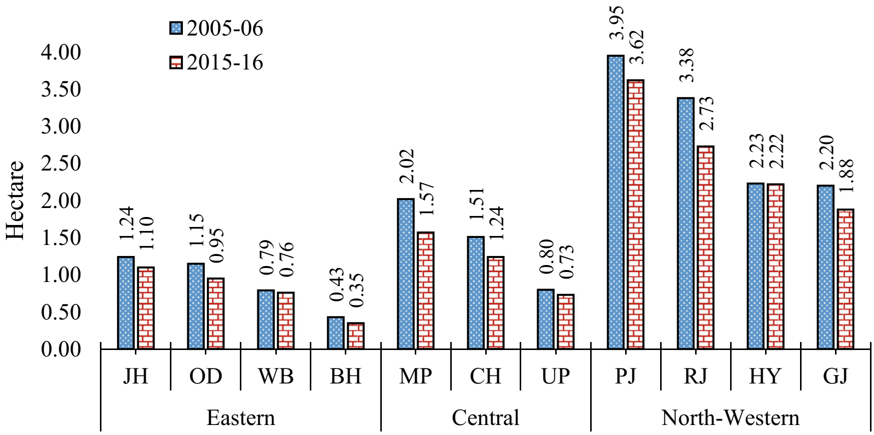


Fig. 6.5 Region-wise farm size (Hectare)

artificial controllability of water with reservoirs, but irrigation intensity helps only in the presence of fertilizer. Reservoir level itself has a significant positive effect. Total labour hours become unproductive in the analysis of efficiency variation of SFA model and while mechanization by both specifications is beneficial for VA, the productivity is lower in alluvial soil. Inputs uses of fertilizer, labour and machines are all affected by economic factors such as their prices relative to crop price and credit and working capital are also important for fertilizer and mechanization. Larger farms seem to use less labour and buy fewer tractors.

6.6 Efficiency Analysis

Inefficiency derived from the SFA has been varied over the sample period, with eastern states like Bihar making enormous improvements while some western states like Punjab, Haryana and Rajasthan became more inefficient. While NW remained most efficient at levels, both E and C gained efficiency over time, and NW became relatively inefficient. The regressions (Table 6.6) show that small farms may be more inefficient, but the negative interaction of farm size and roads suggests that the difference in efficacy effect of farm size may narrow with greater road intensity. Credit has helped to make agriculture more efficient.

Returns from resources treated as an outcome due to east-oriented development policies increased in the lagging states of the east with sustainable and judicious use of resources, making less increasingly wasteful use of the same resources. In fact, behaviours suggest that advanced agricultural states retain a lead but have been generating returns from resources making increasingly wasteful use of them benchmarked by East and Central, whereas arguably, due to east-oriented development

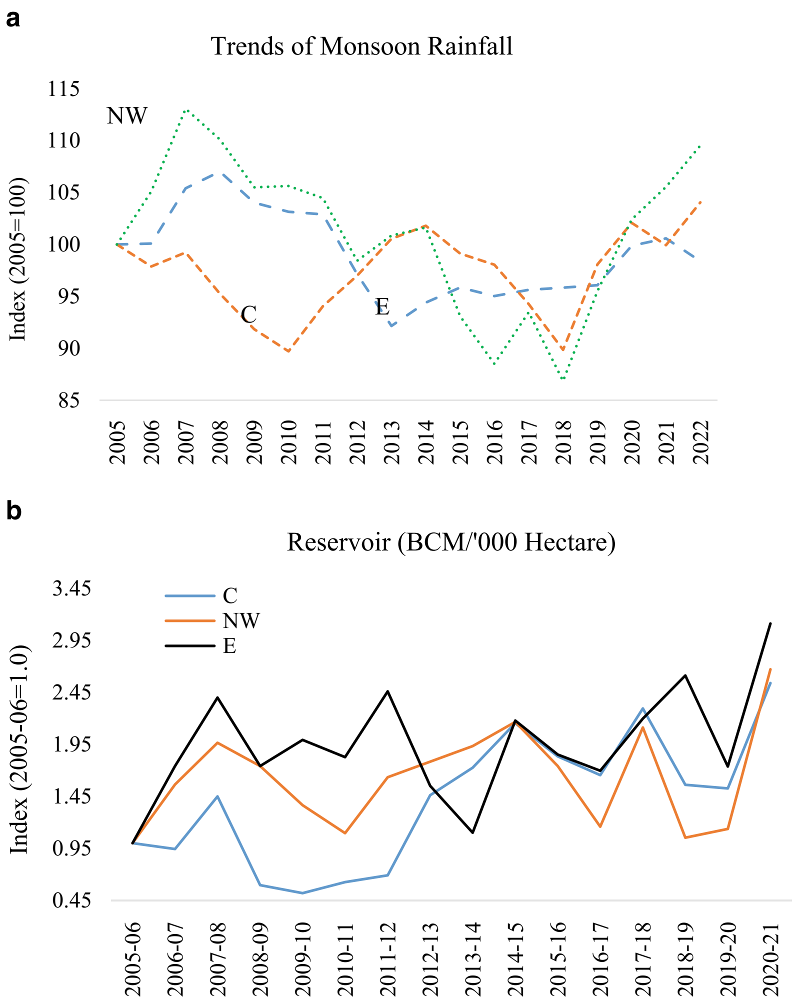


Fig. 6.6 **a** Rainfall average of 5 years. **b** Reservoir water availability in end of the May month

policies, the lagging East is picking up pace, even surpassing NW by judicious use of resources (Figs. 6.10 and 6.11) and (Tables 6.7 and 6.8).

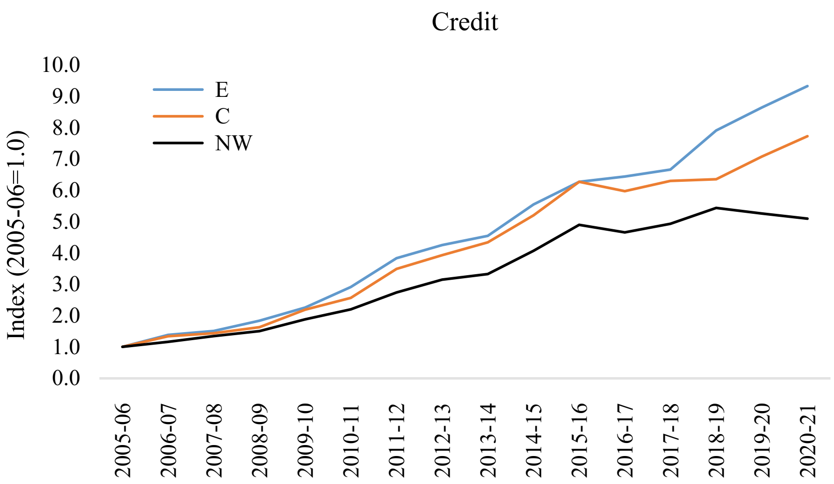


Fig. 6.7 Credit allocation

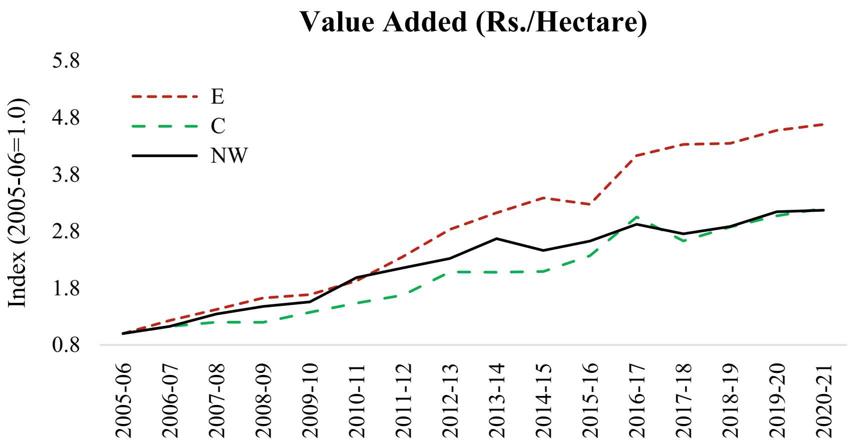
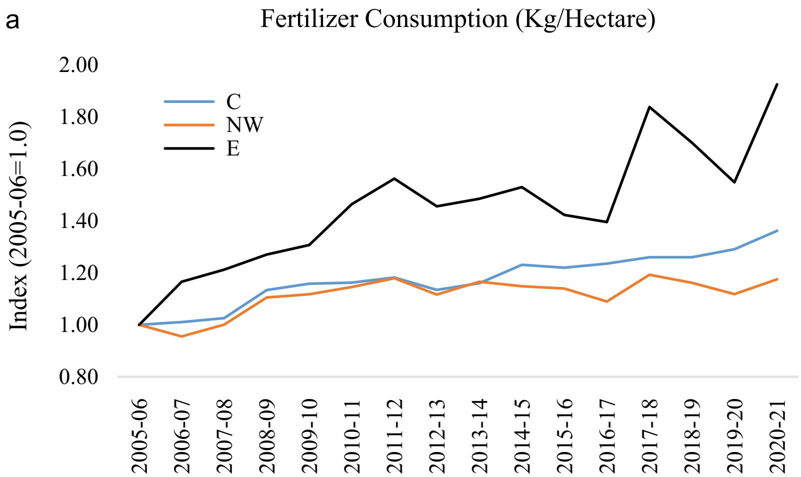


Fig. 6.8 Indices of VA in region wise. *Note* Eastern—BH, OD, JH, WB, Central—MP, CH, UP and North Western—PJ, HY, RJ, GJ



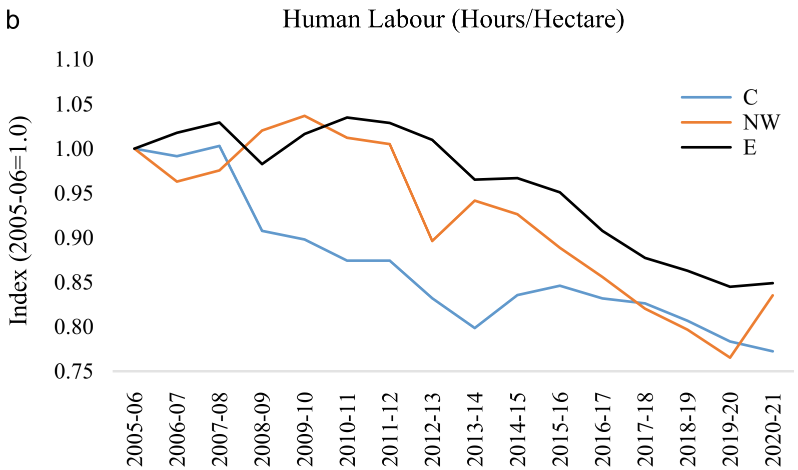


Fig. 6.9 Input use indices

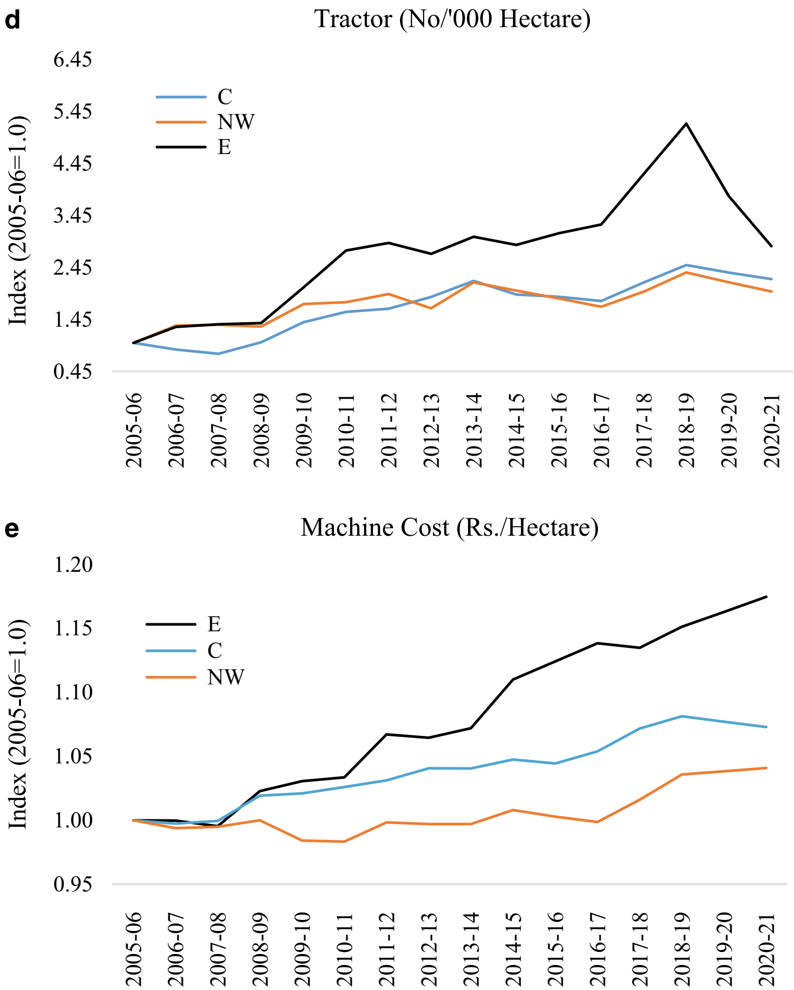


Fig. 6.9 (continued)

6.7 Conclusion

Indian agriculture has come a long way from resource shortage, backward technology, poverty and marker imperfections despite some initiation of infrastructure, irrigation and marketing policy in pre-colonial and colonial status. Independent India, faced with food insecurity, embarked on developments on many fronts to overcome import dependence. India launched the green revolution that delivered the much-sought food sufficiency but, in turn, created many problems like unsustainability, inequity, fiscal burden and political dilemmas that remain to be dealt with even as new developments like the concern for climate change with monsoonal anomalies and the introduction

Table 6.5 Progress in Input use by regions

Year (TE)	Fertilizer consumption (Kg./Hectare)			Human labour (Hours/Hectare)			Well/NSA (Ratio)			RBANK (No./'000 Hectare)		
	C	NW	E	C	NW	E	C	NW	E	C	NW	E
2007–08	96	159	95	542	509	822	0.42	0.45	0.21	0.14	0.11	0.16
2008–09	100	165	102	525	512	817	0.43	0.46	0.21	0.14	0.11	0.16
2009–10	105	173	106	508	525	817	0.44	0.47	0.21	0.14	0.11	0.16
2010–11	109	181	113	485	532	819	0.44	0.48	0.22	0.14	0.12	0.17
2011–12	111	185	121	479	529	831	0.45	0.48	0.23	0.14	0.13	0.18
2012–13	110	185	125	467	505	829	0.47	0.48	0.20	0.15	0.14	0.20
2013–14	110	186	126	453	492	810	0.48	0.48	0.17	0.16	0.17	0.21
2014–15	112	184	125	446	479	794	0.50	0.48	0.13	0.18	0.19	0.22
2015–16	114	186	124	448	477	778	0.51	0.49	0.13	0.19	0.22	0.24
2016–17	117	182	121	454	463	763	0.52	0.49	0.13	0.20	0.23	0.26
2017–18	118	184	130	453	444	738	0.53	0.50	0.13	0.21	0.24	0.28
2018–19	119	185	138	446	428	715	0.55	0.50	0.14	0.21	0.24	0.29
2019–20	121	187	142	437	413	698	0.57	0.50	0.14	0.21	0.24	0.29
2020–21	124	186	145	427	415	690	0.58	0.50	0.14	0.20	0.24	0.29
CAGR (%)	2.0	1.2	3.3	-1.8	-1.5	-1.3	2.5	0.9	-3.0	3.0	6.2	4.7

Source DES, Website, RBI, Website

of ICT promise to transform practices, opportunities and ways we deal with the problems.

Agricultural performance, best approximated by economic returns to farmers or service providers in the farm sector at large in the current perspective, is determined by factors and natural endowments as can be expected, including good soil and water, but further analysis showed how the efficiency of the use of resources also made a difference to the performances across states. While productive use of individual inputs is an important step towards prosperous agriculture, greater efficiency reflects gain from all inputs used in conjunction to deliver more output from the same amount of input or the same output from less input in entirety. Farm income thus depends on conventional inputs, which is influenced by economic factors.

The analysis indicated that the agriculturally advanced states of the north-west that benefitted from the green revolution still yield higher returns due to greater use of inputs but have stable or dipping efficiency. The reason may lie in their use of inputs and entitlement to credit and resultant contribution to sustainability. On the contrary, the water-abundant eastern states lagged behind in value added, but they are performing well in efficiency, and central states are also becoming more efficient in recent times. The small size of the farm, which was unavoidable due to the growth of population, is hampering the attainment of efficiency, but better

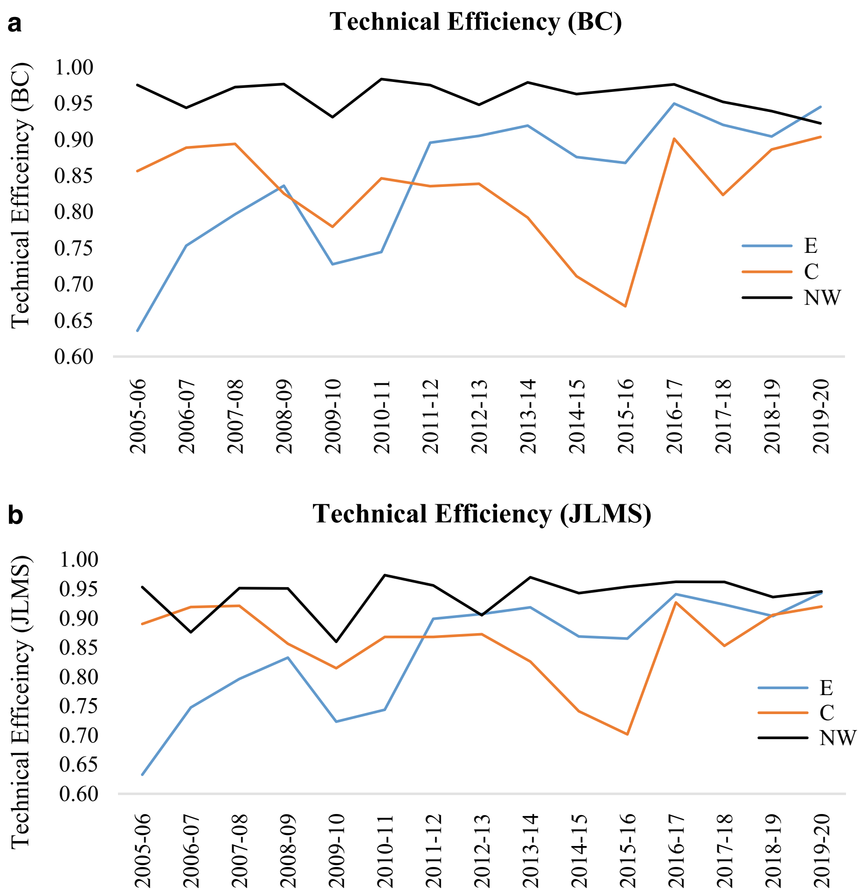


Fig. 6.10 Technical efficiency for region wise based on TRE model (Tractor)

road connectivity and perhaps the marketing avenues created help them recover the loss inefficiency relative to larger farms. Higher credit, a landmark policy instrument to support farmers enhances efficiency. Credit creation has been modernized and expanded with technology and also relaxed and broadened in coverage beyond farming over time.

Table 6.6 Regression to explain Real Value Added (Rs/Hect) in agriculture (VAF)

Variable	Model 1 POOLED	Model 2 (Panel)		Model 3 (Frontier)		Model 4 (Frontier with inefficiency)	
		SPEC: 1	SPEC: 2	SPEC: 1	SPEC: 2	SPEC: 1	SPEC: 2
				Instrumental (IV)			
Irrigation (NIA/ NSA)	–	–	1.696*** (3.30)	–		–	
Fert X Irrigation	0.33*** (4.50)	0.25*** (3.15)	–	0.311*** (4.70)	0.303*** (4.67)	0.311*** (4.84)	0.244*** (3.48)
RESV X Irrigation	0.21*** (4.1)	0.154*** (2.92)	0.233*** (3.15)	0.224*** (4.85)	0.223*** (4.81)	0.219*** (4.87)	0.171*** (3.31)
RESV	0.16*** (3.44)	0.137** (2.55)	0.145** (2.58)	0.130*** (3.79)	0.259*** (6.10)	0.128*** (4.25)	0.186*** (4.47)
Tractor (No/ hectare)	0.21*** (3.75)	0.163*** (2.99)	0.157*** (2.92)	0.403*** (4.25)	–	0.328*** (3.42)	-
Machine (Rs./ Hectare)	–	–	–	–	0.418*** (4.47)	–	0.139 (1.39)
Land Rent	0.71*** (11.74)	0.735*** (10.41)	0.755*** (10.33)	0.352*** (5.97)	0.436*** (6.87)	0.317*** (5.82)	0.353*** (5.31)
Total Labour (hours/hect)	0.08* (1.83)	0.092** (2.07)	0.059 (1.33)	–0.07*** (–6.54)	–0.065*** (–5.50)	–0.07*** (–6.61)	–0.067*** (–4.45)
Rainfall (mm) (3Y M.A.)	–0.00 (–1.18)	–0.000 (–0.55)	–	0.001*** (5.52)	0.001*** (5.22)	0.001*** (6.70)	0.001*** (5.13)
DUM-ALV x Tractor	–0.23*** (–3.61)	–0.113* (–1.72)	–0.096 (–1.49)	–0.28*** (–2.83)	–	–0.28*** (–2.86)	–
DUM-ALV x Machine	–	–	–	–	–0.418*** (–3.30)	–	–0.250* (–1.84)
DUM-ALV	0.56*** (6.04)	0.421*** (3.75)	0.32*** (3.18)	0.953*** (8.50)	4.140*** (3.96)	0.94*** (8.72)	2.738** (2.42)
Constant	2.83*** (5.18)	2.501*** (4.16)	2.66*** (4.11)	5.886*** (12.47)	3.121*** (3.75)	6.01*** (12.81)	5.325*** (5.75)
R^2 Within	–	0.44	0.42	–		–	
Between	–	0.92	0.90	–		–	
Overall	0.79	0.78	0.75	–		–	
Wald chi^2	–	275.3	272.47	637.74	650.15	892.41	645.47
No. of Observation	165	165	176	165	165	165	165
No. of Groups	11	11	11	11	11	11	11

Note Model 1: used POLS Model, Model 2: used panel regression with two different specification, Model 3: used stochastic frontier in two specification (SPEC), (i) SPEC: 1—tractor used and (ii) SPEC: 2—Machine service used and Model 4: Estimated stochastic frontier model with USIGMA option to allows for modelling how inefficiency varies with other variables

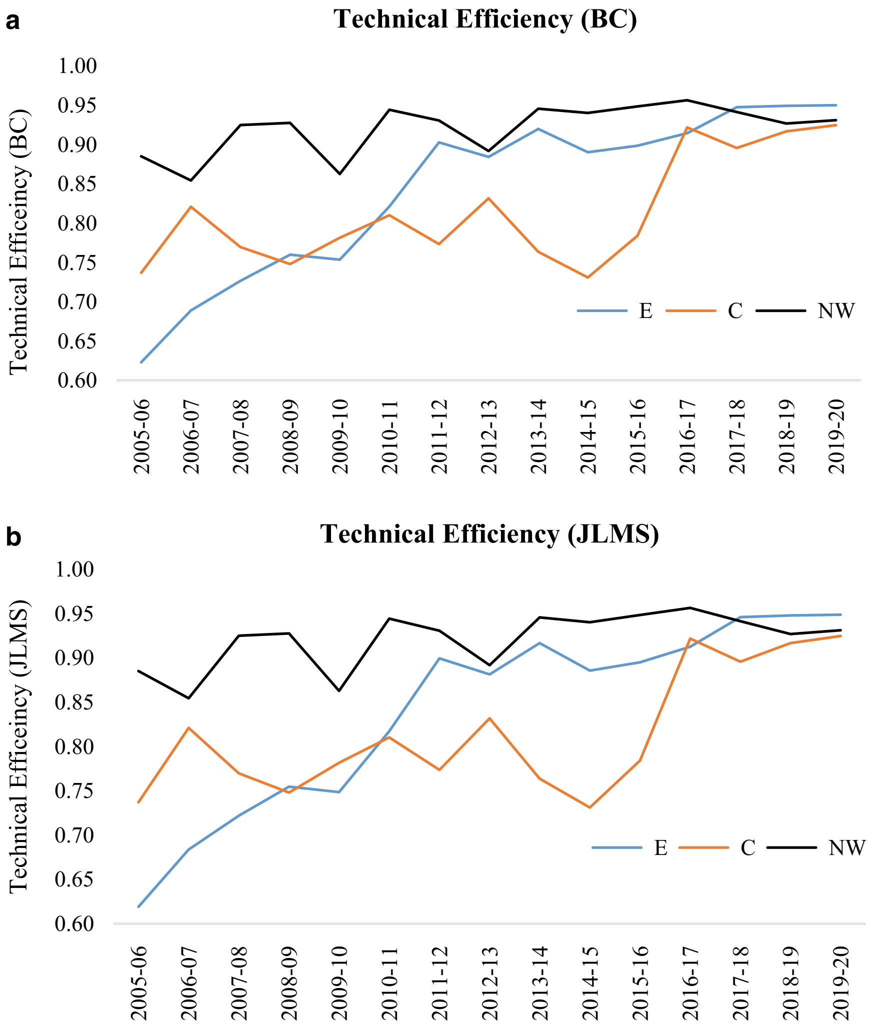


Fig. 6.11 Technical efficiency for region wise based on TRE model (Machine service)

Table 6.7 Regression to explain Input use in agriculture

Variables		Tractor (No./hect)	Machine services (Rs./hect)	Fertilizer (Kg./hect)	Family labour (Hours/hect)	Casual labour (Hours/hect)
Wage/Crop Price		0.31*** (2.80)	–	–	–0.21*** (–4.78)	–0.28*** (–4.92)
Irrigation		–	0.37** (2.10)	0.26*** (3.71)	–	–
Fert Price/Farm Price		–	–	–0.18*** (–4.22)	–	–
Tractor*Farm Size		–	–	–	–	0.17*** (3.71)
Farm Size		–0.31* (–1.96)	–	–	–0.59*** (–4.07)	–0.45*** (–2.96)
Farm Price		–	0.40* (1.74)	–		–
Family labour		–0.36** (–2.01)	–	–		–
RESV		0.23*** (2.72)	–	–		–
RESV X Irrigation		–	–	–	–0.05*** (4.98)	–
Rainfall		–	–	–	–0.12** (–2.02)	–
Rainfall (3y M.A.)		–	–	–	–	0.38** (2.38)
Credit		0.79*** (4.23)	1.17*** (9.49)	–	–	–
Working Capital		–	–	0.81*** (14.12)	–	–
Constant		6.00*** (4.56)	7.12*** (11.60)	2.74*** (11.07)	5.87** (14.03)	2.20** (2.11)
R^2	Within	0.53	0.41	0.65	0.2578	0.21
	Between	0.26	0.48	0.79	0.48	0.59
	Overall	0.40	0.45	0.76	0.47	0.57
Wald chi^2		183.1	121.11	322.82	62.67	57.89
No. of Observation		176	176	176	176	165
No. of Groups		11				
Sample period		2005–06 to 2020–21				

Note Parenthesis figures are z-statistics and ***, **, * denotes the level of significance at 1, 5 and 10%

Table 6.8 Efficiency equation

Variables	Efficiency			
	Model 1		Model 2	
	BC	JLMS	BC	JLMS
Farm size	0.17*** (3.17)	0.17*** (3.17)	0.06** (2.13)	0.07** (2.15)
Credit	0.08** (2.47)	0.08** (2.46)	0.04* (1.83)	0.04* (1.84)
Road x farm size	–0.06*** (–2.99)	–0.06*** (–3.00)	–0.02** (–2.07)	–0.02** (–2.09)
Constant	0.84*** (94.7)	0.84*** (93.2)	0.89*** (176.0)	0.89*** (170.0)

Note Parenthesis figures are z-statistics and ***, **, * denotes the level of significance at 1, 5 and 10%. Model 1: used tractor and Model 2: used Machine service. BC-Battese and Coelli (1992) method for efficiency and JLMS: Jondrow et al. 1982 method for efficiency

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