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Preface

The need for transformation of Indian agriculture is reflected in shifting the development agenda from production to income, food to nutrition, deficit to surplus management, and input-intensive to knowledge-intensive strategies. Further, the ongoing efforts of the government aim to make the agriculture competitive, efficient, profitable and sustainable so as to achieve the goals of doubling farmers' income by 2022, becoming a five trillion dollar economy by 2024-25, and accomplishing sustainable development goals by 2030. Achieving such ambitious goals requires a paradigm shift in the policy space. In view these developments, public policies assume critical role in providing enabling ecosystem for accelerating ongoing agricultural transformation. In agriculture, it assumes as a lead role in improving irrigation and market infrastructure, developing technologies, framing guidelines for sustainable resources use, and providing conducive business environment for attracting investment in agriculture. Therefore, the theme of "Public Policies and Agricultural Transformation in India" was taken for discussion at 29th annual conference of the Association organized at the Odisha University of Agriculture & Technology (OUAT) Bhubaneshwar, Odisha, during 27-29 October 2021.

There has been an overwhelming response from the paper contributors to the conference. The Conference President has recommended 16 papers for publication in full length and the rest in the form of abstracts. The publication in the form of an abstract in any way does not reflect quality and content of the papers. The Association is grateful to Dr P K Agrawal, Vice-Chancellor, Odisha University of Agriculture & Technology (OUAT), Bhubaneshwar for consenting to host the Conference at very short notice. The Association is also grateful to Dr K K Rout, Dean, College of Agriculture and College of Forestry, Dr H K Patro, Director of Planning, Monitoring and Evaluation for guiding the organizational activities, and to Dr Sarba Narayan Mishra, Professor & Head, Department of Agricultural Economics, for shouldering the responsibility of Organizing Secretary for the Conference.

The Association is grateful to the Indian Council of Agricultural Research (New Delhi) for providing continuous financial support for the publication of the regular issues of the journal *Agricultural Economics Research Review* and also for organization of the Annual Conference. The National Bank for Agriculture and Rural Development (Mumbai) provided financial assistance to publish papers and proceedings of the Conference in a special issue of the *Agricultural Economics Research Review*, which is acknowledged with thanks. The Association is also thankful to Dr RT Doshi Foundation (Mumbai) for annually sponsoring two prizes for the best presentations at the Conference and also two prizes for the best papers published in the *Agricultural Economics Research Review*. International Food Policy Research Institute (IFPRI), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and The International Potato Center (CIP) have sponsored their technical sessions in the Conference.

Prof D K Marothia, Conference President and Dr P K Joshi, President, AERA have taken keen interest in various activities and program of the conference. Special thanks are due to Prof. Vasant Gandhi for delivering Dr GK Chadha Memorial lecture. Led by Dr P S Birthal, Chief Editor, *Agricultural Economics Research Review*, a team consisting of Dr Girish Kumar Jha, Dr Shivendra Kumar Srivastava, Dr Sendhil R Dr Subash S P, and Dr Kiran Kumar assisted the

Conference President in developing the conference theme, and subsequently screening of the papers for presentation at the conference. Similarly, all office-bearers of the Association, particularly Dr P Kumar, Chairman of the Editorial Board and Dr Surabhi Mittal, Joint Secretary, have contributed in several ways to bring out the conference and regular issues of the journal. I take this opportunity to thank all of them for their cooperation and untiring efforts. Let me also thank eminent scholars for reviewing the articles for the journal.

We are grateful to all the invited speakers at the conference and the paper contributors for submitting their excellent work. I sincerely thank chairs of different sessions and all other colleagues who have accepted various scientific responsibilities to conduct proceedings of the Conference.

Suresh Pal
Secretary
Agricultural Economics Research Association (India)
New Delhi 110 012

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Welfare gains of inward-looking: an *ex-ante* assessment of general equilibrium impacts of protectionist tariffs on India's edible oil imports

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Abstract Import substitution policies are often *inward-looking* in trade deliberations. The present study is an attempt to quantify the likely benefits of protectionist tariff hikes in enhancing domestic production and improving producer prices. It takes the case of the edible oil imports of India and estimates the price gains the oilseed producers (farmers) and the processing industries may receive; likely increase in domestic oilseeds and edible oil production, and the role the technology in attaining oilseeds/edible oil self-sufficiency. A three-sector open-economy Computable General Equilibrium (CGE) model is calibrated to a 2017-18 SAM developed for this purpose. Tariff hikes are assumed in different protectionist scenarios and their impacts on production and prices are simulated. Total Factor Productivity (TFP) estimates are derived for the oilseeds (2005-18) and the edible oil (2014-18) sectors to understand the technological penetration there. The price gains vary between 2.4% and 6% to the oilseeds producers and between 1.2% and 2.9% to the edible oil industries. The oilseeds production may enhance by 1.8% at maximum, and the edible oil production by 2.9%. The existing TFP growth is inadequate to move towards oilseeds/edible oil self-sufficiency. This demands a shift in production technology.

Keywords Import substitution, oilseeds, edible oil, SAM, CGE, India

JEL Codes E16, E17, F14, F17, O53

India's intellectual and policy communities are often noted to embrace *self-reliance* or in other words, the *atmanirbhar* strategy, abandoning export orientation and disfavoring liberalizing trade (Chatterjee and Subramanian 2020) in manufactured goods. Even in the case of agriculture, the country's stance is observed to be static, noting the region levying the highest tariffs on its imports of most of the agricultural products (Beckman and Scott 2021). Such policies are claimed to be instrumented to protect and benefit the domestic industries and farm communities by the proponents, which, in turn, is perceived by the opponents as an *inward-looking* strategy that shall demote the nation's growth and welfare. The pursuit of *cereal self-sufficiency* policy it succeeded remains hard to replicate in enhancing oilseeds production. The country meets to date around 60% of its domestic edible oil demand through imports (GoI 2021a).

Much of these imports emerge from very few countries. India imports around 54% of palm oil from Indonesia and 37% from Malaysia[1]. Such heavy dependency costs over the long run not just on the public exchequer but may turn the domestic consumer market vulnerable to the international price shocks. Persisting imports also signal limited response in the domestic production

[1]In value (nominal) terms; estimated based on imports in the years 2019-20 & 2020-21.

system to the demand. For instance, while edible oil imports grew by about 6.8% a year[2] during 2001-11, domestic edible oil production grew by just 2.2%. To this end, the states of Andhra Pradesh and Telangana show prospects for augmenting domestic contributions. These two states together produced around 97% of the crude palm oil production in the TE 2019-20 (GoI 2021b). The state of Andhra Pradesh produced as much as 84% of the total crude palm oil.

At the policy front, initiatives focusing on self-sufficiency in oilseeds and edible oil production date back to the 1980s. The Government of India launched Technology Mission on Oilseeds (TMO) in May 1986 to enhance oilseeds production and productivity, hence increasing the domestic edible oil production. In the year 1992-93, oil palm was brought into the ambit of the Mission. The Oilseeds Production Programme (OPP) and the Oil Palm Development Programme (OPDP) were brought under the Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM) that came into operation in April 2004. In the year 2014, the ISOPOM together with the Integrated Development of Tree Borne Oilseeds and Oil Palm Area Expansion (OPAE) were under the National Mission on Oilseeds and Oil Palm (NMOOP). To boost the efforts further, in August 2021, the Union Cabinet approved the launch of a new scheme named National Mission on Edible Oils – Oil Palm (NMEO-OP).

These policies helped to enhance both oilseeds and edible oil production but were not on par with the rise in demand. During the period 2004-14, both oilseeds and edible oil production grew around 4% a year. But the domestic demand has been much stronger, resulting in edible oil imports growing by 9.6% a year. On the other side, notably in the case of oil palm, while the statistics show the crop is cultivated in about 0.35 million hectares, the potential exists to bring as high as 2.8 million hectares of additional land under cultivation (GoI 2021b). The policies that encourage oilseeds and edible oil production in the country shall help to reduce the drain on import bills and help to generate income and employment.

Tariffs shall be an effective instrument to make imports expensive. Tariff hikes curb imports in a competitive economy, triggering domestic firms and farms to expand their production. While the non-tariff barriers act similarly, the former has been the common instrument in India to regulate domestic prices and imports in the case of oilseeds/edible oils in India. In the present study, we construct a hypothetical economy that attempts to raise tariffs for the edible oils it imports to encourage domestic oilseeds and edible oil production. We then estimate potential economy-wide impacts of this hike calibrating a 3-sector Computable General Equilibrium (CGE) model to a Social Accounting Matrix (SAM) representing the Indian economy, focusing on the production and price gains to the farmers and the domestic edible oil industries. We estimate then the Total Factor Productivity (TFP) growth in both sectors to observe the potential role technology can play in rising production. The results indicate that both the farmers and the edible oil industries enhance their production and receive better prices when tariffs are hiked, hence raising their welfare. But the TFP growth estimates suggest the present rate of technology growth may barely be sufficient to bridge the gap in production caused by these hikes, calling for the need to enhance the technology in both the oilseeds and the edible producing sectors that shall enhance the outputs rapidly.

Materials and methods

Data

Data on oilseeds production and costs and returns are gathered from statistics published by the Department of Agriculture, Cooperation and Farmers Welfare (Ministry of Agriculture & Farmers Welfare). The domestic edible oil production, imports, and tariff rates are collected from the Department of Food and Public Administration (Ministry of Consumer Affairs, Food and Public Distribution) for the aggregate level. The details of import statistics at the commodity level are obtained from the Department of Commerce (Ministry of Commerce and Industry). For estimating TFP growth in oilseeds, the information contained in the Cost of Cultivation (CoC) is used covering the period 2004-05 to 2017-18. The TFP growth in the edible oil industry is estimated for the period 2013-14 to 2017-18 using the statistics published in the reports of the Annual Survey of Industries (Ministry of Statistics and Programme Implementation). The nominal values are deflated using GVA, GCF, and CPI (Urban) indices

[2]CAGR, estimated with a 3-year moving average series

respectively in the case of the edible oil industry with the 2011-12 base[3]. Physical quantities are used in estimating TFP in oilseeds, and GVA (Agriculture and allied sector) deflators with 2011-12 base are used to derive the irrigation and insecticide expenses in real terms.

A Social Accounting Matrix (SAM) is developed to assess the economy-wide impacts when tariff-hikes are imposed. The IFPRI's Social Accounting Matrix for India for the year 2017-18 (Pal et al. 2020) is used as the base. This matrix differentiates economic *activities* and *commodities* under 112 categories. To focus on the present objective, at stage-1, this *standard* version is collapsed to form a 3-sector version accommodating oilseeds, edible oils, and all others. The oilseeds covered groundnut, rapeseed and mustard, and all others. Further, the 13-factor components in the original version are clubbed to form two basic factors namely labour and capital; and households and firms are differentiated into just farmers and all others. In stage-2, this collapsed version is further simplified to follow Lofgren (2003). The panel of SAM constructed for the present study is outlined in Table A1 (in the appendix). A three-sector open-economy CGE model is calibrated following the author mentioned above, the details of which are discussed under the methodology section.

The Computable General Equilibrium (CGE) model

The costs of protection vary with the type of inquiry one adopts to estimate. One follows either a Partial Equilibrium (PE) or a Computable/Applied/ General Equilibrium (CGE/AGE/GE) model. The former allows one to observe impacts at a finer level but within a sector or among a group of classes within a sector. The CGE models are effective in capturing both direct and indirect repercussions within and outside the sector intervened, like the impacts on production and X-efficiency, prices, employment, and income, among others. A CGE model comprises a set of nonlinear equations, to describe mathematically. As the present study explores cross-sectoral effects, the CGE based approach is followed. The study adopts the models and equation sets discussed in Lofgren (2003). The equations solved are listed in Table A2 (in the appendix). As the author states, this system reflects a critical minimum of real-world features laying a foundation for country-specific detailed policy analysis.

Oilseeds and edible oils are specified as non-exported commodities and the former as non-imported commodities. Labour employed in respective activities is estimated from the Periodic Labour Force Survey 2017-18 (GoI 2019), together with the crop production estimates of 2019-20 (GoI 2021b). Farmers and other nonfarm households earn their incomes by offering labour and capital services and spending on food and non-food commodities. The oilseeds and the edible oil production technologies follow the Cobb-Douglas form. Imperfect substitutability is presumed among the domestic and the imported commodities and is captured by the Constant Elasticity of Substitution (CES) aggregation function. Trade elasticities are adopted from Imbs and Mejean (2010). Investment drives savings; capital is activity-specific and fully employed; labour is mobile and receives fixed wages; flexible exchange rate clears current account.

Malmquist Productivity Index (MPI) and Data Envelopment Analysis (DEA)

The Malmquist Productivity Indices (MPI) are estimated to observe the TFP growth in both oilseeds and the edible oil sectors. These TFP growth rates shall provide an idea of technology growth one might expect in these sectors in the coming years and hence their contribution to oilseed and edible oil production. Introduced by Malmquist (1953), the approach has undergone improvements (Caves et al. 1982 a&b; Färe et al. 1994; Bjurek 1996; Lovell 2003) and is widely applied (Fulginiti and Perrin 1998). These indices are estimated using the Data Envelopment Analysis (DEA), a nonparametric piecewise linear frontier. It allows for technical inefficiencies, unlike the parametric approach that assumes outputs are technically efficient. Advantage also lies in its constructability in the absence of prices of inputs and outputs. The indices are deterministic and avoid specification bias. The index identifies TFP growth concerning two time periods through a quantitative ratio of distance functions. We follow the output-based Malmquist index of productivity change to estimate the growth of TFP as it estimates the maximum level of outputs that can be produced using a given input vector and a production

[3]2012=100 for CPI(Urban)

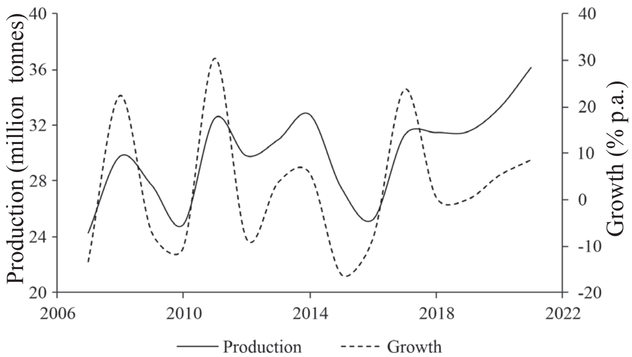

Figure 1 Production and growth in oilseeds (All-India, 2007-2021)
Source Ministry of Agriculture & Farmers Welfare
Note Growth estimates are in the secondary axis

technology relative to the observed level of outputs (Coelli et al. 2005). It estimates the radial distance of the observed output vectors in periods *t* and *t+1* relative to a reference technology. A detailed discussion is made in Method A1 (in the appendix).

Results and discussion

Performance in oilseeds production

The oilseeds production has increased gradually, from 28 million tonnes in 2005-06 to 33 million tonnes in 2013-14. Since the NMOOP was introduced, production has grown faster reaching 36 million tonnes in 2020-21. Still, production has remained highly volatile, not subduing over years (Figure 1). For instance, growth was as high as 31% in 2010-11 but was -16% in 2015-16. While such volatility has remained over years, which determines the level of edible oil production by the domestic industries, demand for edible oils at the consumer market has witnessed a stable growth with rising income and population, necessitating imports.

While the performance at the sectoral level shows positive growth, the growth in different oilseed commodities produced, especially since TE 2014-15, shows that the positive growth is limited to a few but major commodities (Table 1). Soybean, rapeseed and mustard, and groundnut together contribute around 92% to the total oilseeds produced, and these were the only crops to grow at a positive rate since TE 2014-15. The soybean production, which contributes over 37% of total oilseeds produced, has grown by 1.8%. This has been about 5.2% and 3.1% in rapeseed and mustard and groundnut, whose contributions are about 28% and over 26%, respectively. On the other side, the safflower production has declined over 15%, the sunflower over 12%, and the niger seed over 11%. Castor seed, sesamum, and linseed are the other oilseeds to witness negative production growth.

The oilseeds production has undergone a notable change since the NMOOP was introduced. The negative production growth shifted to a positive rate in the case of groundnut in the period TE 2015-21 when comparing the period TE 2008-14. While growth was -1% a year during the former period, it was over 3% in the latter. Similar is the case in rapeseed and mustard production. The production growth of 1.6% a year in the former period rose to 5.2% in the latter. The sunflower production, which was declining at the rate of over 16% also moderated to over 12% a year since TE 2014-15. Thus, performance has shifted to a positive side since the scheme came into operation. But the opposite was the case in other commodities. The soybean production has declined from over 6% to around 2%; castor seed production from around 15% to -3.2%; sesamum production from 2.7% to -1.7%; niger seed production from -2.5% to -11.6%; linseed production

Table 1 Growth in oilseeds production (All India, 2008-2021)

Oilseeds	Season	Growth* (% p.a.)	
		TE 2008-14	TE 2015-21
Groundnut	Kharif	-1.2	3.9
	Rabi	-0.1	0.1
	Total	-1.0	3.1
Castor seed	Kharif	14.9	-3.2
Sesamum	Kharif	2.7	-1.7
Niger seed	Kharif	-2.5	-11.6
Soybean	Kharif	6.1	1.8
Sunflower	Kharif	-16.6	-9.8
	Rabi	-16.6	-14.5
	Total	-16.6	-12.8
Rapeseed & mustard	Rabi	1.6	5.2
Linseed	Rabi	-2.4	-3.7
Safflower	Rabi	-10.5	-15.5

Source Authors' estimates based on Ministry of Agriculture & Farmers Welfare
Note *CAGR estimates based on 3-year moving averages

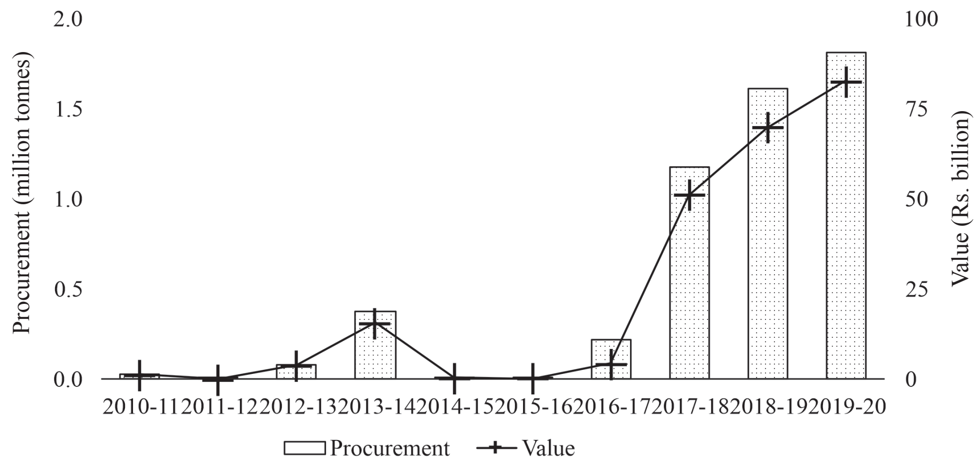

Figure 2 Oilseeds procurement under Price Support Scheme (PSS)
Source National Agricultural Cooperative Marketing Federation
Note Values are in the secondary axis

from -2.4% to -3.7%; and safflower production from -10.5% to -15.5%. Thus, the production growth of groundnut and rapeseed, and mustard has been at the cost of fall of production in the rest of the commodities.

Part of the reason for expansion in oilseeds production in recent years is the rise in oilseeds procurement by the Government. Observing the procurement trend since 2010–11, one shall point out it was only since 2017–18 the oilseeds procurement crossed more than a million tons (Figure 2). Leaving the years 2013-14 and 2016–17, none of the years witnessed substantial procurement. In the past three years, the government has procured about 4.6 million tonnes of oilseeds costing over Rs. 200 billion.

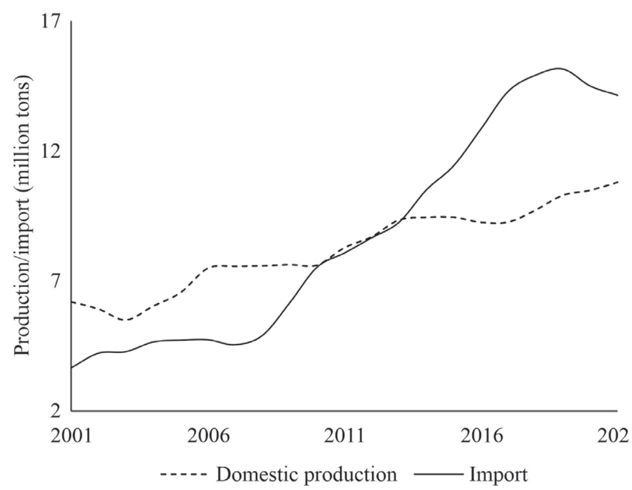

Figure 3 Domestic production and imports of edible oil in India
Source Ministry of Consumer Affairs, Food & Public Distribution
Note Trend lines are based on 3-year moving averages

Edible oils sector: domestic capacity and import dependency

All these efforts to raise the oilseeds production have helped rising domestic edible oil production but not to the rate of expansion in demand. With a rise in oilseeds production, domestic edible oil production has increased from 6.2 million tonnes in the year TE 2001 to 10.8 million tonnes in TE 2021 (Figure 3), growing at a rate of 3.2% a year. To the other end, the domestic demand has grown by 5.7% a year, demanding the edible oil imports to grow by 8.3% a year. The country imported about 14.2 million tonnes of edible oil in TE 2021, which was about 3.7 million tonnes in TE 2001.

Import basket mostly consists of crude and refined palm oils, soybean, and sunflower oils (Table 2). The former two categories make the major pie. Around 79% of the imported oils were crude and refined palm oils in the year 2009–10. More than half of all edible oils imported to date is crude palm oil, refined by the domestic industries. To date, this has remained to be the largest edible oil item imported. While the share of the refined has remained more or less stable, the share of crude palm oil has consistently declined with a rise in soybean and sunflower oil imports. For instance, the share of crude palm oil has declined from 62.6% in the year 2009–10 to 55.4% in 2020–21. During the same time, the import of soybean oil has risen from 13.7% to

Table 2 Share of major edible oils in total imports (%)

Year	Crude Palm Oil	Refined Palm Oil	Soybean Oil	Sunflower Oil	Others	Total
2009-10	62.6	16.3	13.7	6.5	0.9	100.0
2010-11	61.9	12.6	16.4	8.9	0.2	100.0
2011-12	63.2	16.1	10.6	9.2	0.8	100.0
2012-13	65.6	12.9	10.2	10.3	1.0	100.0
2013-14	51.5	24.4	12.8	10.3	1.0	100.0
2014-15	56.3	9.4	18.2	13.5	2.7	100.0
2015-16	46.6	16.5	25.3	9.5	2.1	100.0
2016-17	38.6	21.0	24.7	12.3	3.3	100.0
2017-18	44.7	18.1	20.5	14.6	2.2	100.0
2018-19	43.6	16.8	21.2	17.2	1.2	100.0
2019-20	43.2	16.5	22.6	17.1	0.6	100.0
2020-21	55.4	1.0	26.9	16.1	0.5	100.0

Source Authors' estimates based on Ministry of Commerce and Industry

26.9%, and the sunflower oil has more than doubled from 6.5% to 16.1%, respectively. A decline in the rate of soybean production in the country – as noted earlier, and a consistent fall in sunflower production could be the major reason behind such change.

Tariff hikes: scenarios, simulations, and impacts

The present rates of duties for edible oil imports are shown in Table 3. In general, crude forms attract lower tariffs when compared with the refined oil categories. One shall observe the difference is fixed at 11% between the crude and refined forms. This helps domestic processing companies enhance their outputs and profits and acts as a means for generating and maintaining employment in these industries. Crude palm oil attracts the lowest tariff at present among all edible oil categories. Having the largest import share backed by strong domestic demand, it's not uncommon to observe the Government maintaining this tariff highly flexible to adjust to the oilseeds production and consumer edible oil prices in the country. It is also common to observe a co-movement in tariff hikes in both the crude and the refined forms simultaneously in most cases. Higher tariffs are maintained in recent years, possibly to enhance the domestic production capacity - especially since late 2017 when compared with the previous years. One shall correlate these hikes with higher oilseeds production and procurement discussed earlier.

Table 3 Import duties on edible oils (%, w.e.f. 30th June 2021)

Products	Rate	Agri Cess	Social Welfare Cess	Effective Duty
Crude palm oil	10.00	17.50	10.00	30.25
RBD palmolein	37.50	-	10.00	41.25
RBD palm oil	37.50	-	10.00	41.25
Crude soybean oil	15.00	20.00	10.00	38.50
Crude sunflower oil	15.00	20.00	10.00	38.50
Crude rapeseed oil	35.00	-	10.00	38.50
Refined soybean oil	45.00	-	10.00	49.50
Refined sunflower oil	45.00	-	10.00	49.50
Refined rapeseed oil	45.00	-	10.00	49.50

Source Solvent Extractors' Association of India

Table 4. Tariffs assumed under different scenarios

Item	Tariff rate (%)						
	Base	S-1	S-2	S-3	S-4	S-5	S-6
Crude palm oil	30.25	48.40	37.81	45.38	48.40	37.81	45.38
RBD palmolein	41.25	59.40	51.56	61.88	59.40	51.56	61.88
RBD palm oil	41.25	59.40	51.56	61.88	59.40	51.56	61.88
Crude soybean oil	38.50	38.50	48.13	57.75	38.50	48.13	57.75
Crude sunflower oil	38.50	38.50	48.13	57.75	38.50	38.50	38.50
Crude rapeseed oil	38.50	38.50	48.13	57.75	38.50	48.13	57.75
Refined soybean oil	49.50	49.50	61.88	74.25	49.50	61.88	74.25
Refined sunflower oil	49.50	49.50	61.88	74.25	49.50	49.50	49.50
Refined rapeseed oil	49.50	49.50	61.88	74.25	49.50	61.88	74.25

Source Authors (rates in scenario-1 are based on the Ministry of Consumer Affairs, Food & Public Distribution)
Note Base rates are the present tariff rates; S-1 through S-6 refer to the scenarios

The present study attempts to simulate an economy that attempts to encourage its domestic production capacity. As an *ex-ante* measure, different scenarios are assumed. In scenario-1, the country is presumed to impose the highest tariffs it levied in past on different edible oil items, expecting to increase its domestic production and processing capacities. One shall note that leaving palm oil, the tariff rates at present are equivalent to the highest rates in past. This protectionist approach is presumed to intensify in scenarios 2 and 3 where an additional 25% and 50% tariff hikes are presumed over the existing rates. The latter three scenarios follow the former, the exception being an absence of a hike in crude and refined sunflower oils as its seed production trend has sharply declined for more than a decade. Tariff rates presumed in different scenarios are displayed in Table 4. One shall note the tariff rates are similar in scenarios 1 and 4 as the base rates are equivalent to the highest tariff in past for the crude and refined sunflower oil category. Net tariff rates are derived for the edible oil sector using nominal import values of different items during 2019-20 as weights[4] and were used in the simulation.

The aggregate tariff hikes over the base rates derived under different scenarios and their probable impacts on selected attributes are displayed in Table 5. In all the scenarios, a tariff hike raises import prices and hence reduces the edible oil imports as common to expect, with the volume of reduction varying with the level of tariff hikes. For instance, in scenario-3, which levies the highest tariff, the results indicate that the edible oil import shall decline by over 20%. The rate varies to over 16% in scenario-6; around 12% in scenarios-1&4 that replicates the highest tariffs levied in past; and lesser in other cases. Note that the rate of decline responds together with the import substitution elasticity, which is held constant in different scenarios. This reduction in import boosts both the domestic oilseeds and edible oil production – but marginally. In scenario-3, which levies the highest tariff, oilseeds production rises just around 2%, and edible oil production increases by around 3% in response to the decline in import by over 20%. One shall observe similar effects in other scenarios as well in varying rates.

These tariff hikes and subsequent rise in oilseeds production still bring higher prices to the farmers and the edible oil industries, primarily due to the persisting gap between the domestic demand and the supply after the hike. Results show this price gain shall vary from 2.4% to 6% depending upon the tariff imposed. The scenario-5, which excludes sunflower oil from tariff imposition, generates lower price gains at an aggregate level, whereas scenario-3 brings the highest gain, among others. Price gains to the processing industries are relatively less when compared with the oilseed

[4]Item-1 also included *crude palm kernel oil*; item-3 included *RBD palm stearin* and *other refined palm oil*; and item-6 included '*rape oil*' while estimating net tariff.

Table 5 Simulation results: impact of tariff hikes

Impacts	Scenarios					
	1	2	3	4	5	6
Tariff hike (% over the base rate)	27.54	25.00	50.00	27.54	19.71	39.42
Price effects						
The domestic price of domestic output						
a. Oilseeds	3.3	3.0	6.0	3.3	2.4	4.7
b. Edible oil	1.6	1.5	2.9	1.6	1.2	2.4
Import price						
a. Oilseeds	-	-	-	-	-	-
b. Edible oil	4.7	4.3	8.5	4.7	3.4	6.7
Composite commodity price						
a. Oilseeds	3.4	3.0	6.0	3.4	2.5	4.8
b. Edible oil	2.4	2.1	4.1	2.4	1.6	3.3
Producer price						
a. Oilseeds	3.3	3.0	6.0	3.3	2.4	4.7
b. Edible oil	1.6	1.5	2.9	1.6	1.2	2.4
Production effects						
Quantity of domestic output						
a. Oilseeds	1.0	0.9	1.8	1.0	0.8	1.5
b. Edible oil	1.7	1.5	2.9	1.7	1.2	2.3
Quantity of imports						
a. Oilseeds	-	-	-	-	-	-
b. Edible oil	-11.9	-10.8	-20.4	-11.9	-8.7	-16.5

Note $\sigma_{md} = 4.874$; $\Omega_{ed} = 2.771$

producers, ranging between 1.2% and 2.9%. Overall, the results suggest tariff hikes signal moderate but positive impacts on domestic oilseeds and edible oil production but considerable price gains – especially to the farmers.

Technological potential

The positive impact on production and prices discussed above shall help to enhance both oilseeds and edible oil production in the country. But the observed rate of increase in production is considerably low when compared to the domestic demand. Enhancing production and processing technology shall be a viable option to produce more per unit of land with existing rates of inputs used in the oilseeds sector, and to process more with the level of labour and capital employed in the edible oil sector. The pattern of change over the years in the oilseeds producing sector indicates a lower rate of yield growth in most of the commodities (Table A3 in the appendix). Except for soybean, average yield levels have increased in several edible oil commodities across states. While the use of labour has been substituted increasingly with machine power and a higher rate of fertilizers and pesticides are applied, the decline in irrigation expenses in most cases raises concerns about sustaining the existing yield growth in the long run. Similar is the case of the edible oil industries. While a substantial rise in the capital is an encouraging feature (Table A4 in the appendix), this has been at the cost of stagnant labour intake. With falling labour and other inputs use, the income and profit gains have been moderate in recent years.

The TFP growth estimates show considerable variations when compared with the past. The estimates of Chand et al. (2012) show a positive but less than unitary growth during 1975-05 in major oilseeds like soybean, groundnut, rapeseed and mustard (0.71%, 0.77%, and 0.79% respectively). Chandel et al. (2007) report a negative growth in the case of soybean (-0.06%), positive but lower growth in groundnut (0.39%), and

Table 6 Total Factor Productivity (TFP) growth in oilseeds and edible oil industry

Sector/Commodity/State	TFP Growth (% p.a.)
Oilseeds (2004-05 to 2017-18)	
Groundnut	4.58
Sesamum	-0.95
Soybean	-0.93
Rapeseed & mustard	0.06
Sunflower	4.58
Total oilseeds	1.47
Edible oils (2013-14 to 2017-18)	
Andhra Pradesh	-36.5
Assam	-2.1
Bihar	5.1
Gujarat	-3.3
Haryana	1.5
Himachal Pradesh	15.8
Jammu & Kashmir	-0.2
Jharkhand	-3.6
Karnataka	-9.1
Kerala	10.3
Madhya Pradesh	-15.2
Maharashtra	-41.5
Odisha	7.8
Punjab	4.5
Rajasthan	6.9
Tamil Nadu	-0.4
Uttar Pradesh	2.3
Uttarakhand	-13.6
West Bengal	2.6
All states	-3.52

a more than unitary growth in rapeseed and mustard (2.41%) while studying the period 1981-00. Kumar et al. (2008) observe an improvement in TFP growth from 0.14% during 1971-86 to 0.33% during 1986-2000. The present study, which extends the period of analysis to 2005-18, obtains a lower but positive TFP growth in rapeseed and mustard (0.06%), higher growth in the case of groundnut (4.6%), and negative growth in soybean (-0.93%) (Table 6). The sunflower, despite a persistent fall in production, observes a higher TFP growth while the sesamum has negative growth.

The higher TFP growth in groundnut is a reason why the production shifted towards a higher growth trajectory in the recent past *i.e.* groundnut production growth shifted from a negative annual rate of -1% during TE 2008-14 to 3.1% during TE 2015-21. The case of sunflower needs further probe. Turning our attention to the negative TFP growth in the edible oil industries both at the national level and across some major states, a persistent fall in capacity utilization in the industry shall in part be taken for validation. The capacity utilization averages just to 46%, falling from 65% five years earlier, often explained by the stagnant oilseed production trend. Despite the differences in numerical TFP growth estimates in both oilseeds and edible oil industries, one shall observe the existing rate of technology growth may barely help to expand the domestic production of these commodities.

Conclusions

Tariffs shall be an effective instrument to make imports expensive. The present study attempted to quantify the likely benefits of protectionist tariff hikes in enhancing domestic production and improving producer prices. Taking the case of the edible oil imports in India, it estimated the price gains the oilseed producers (farmers) and the edible oil industries shall receive; likely increase in domestic oilseeds and edible oil production, and the role the technology in attaining oilseeds/edible oil self-sufficiency. To quantify the impacts of tariff hikes, it calibrated a three-sector open-economy Computable General Equilibrium (CGE) model calibrated to a 2017-18 SAM developed for this purpose. Tariff hikes were assumed in different protectionist scenarios and their impacts on production and prices were simulated. In scenario-1, the country was presumed to impose the highest tariffs it levied in past on different edible oil items, expecting to increase its domestic production and processing capacities. This protectionist approach was presumed to intensify further in scenarios 2 and 3, where an additional 25% and 50% tariff hikes were presumed over the existing rates. The latter three scenarios followed the former, the exception being an absence of a hike in crude and refined sunflower oils as its seed production trend has sharply declined for more than a decade. Total Factor Productivity (TFP) estimates were derived for the oilseeds (2005-18) and the edible oil (2014-18) sectors to observe the existing rate of technology growth.

Results showed a tariff hike raises import prices in all scenarios and hence reduces the edible oil imports, with the volume of reduction in imports varying with the level of tariff hikes. This reduction in import boosts both the domestic oilseeds and edible oil production – but marginally. These tariff hikes and subsequent rise in oilseeds production still bring higher prices to the farmers and the edible oil industries, primarily due to the persisting gap between the domestic demand and the supply after the hike. The price gains were predicted to vary between 2.4% and 6% to the oilseeds producers (farmers) and between 1.2% and 2.9% to the edible oil industries. The oilseeds production was predicted to enhance by 1.8%, and the edible oil production by 2.9% at maximum. The existing rates of TFP growth were low, hence inadequate to meet self-sufficiency in oilseeds hence in edible oils, demanding a shift in production technology. With a huge share of land under oilseeds operated by the marginal and smallholders in resource-poor environments, policies that incentivize to bring more area under oilseeds and invest more for better yield shall help to enhance production in the medium and long run.

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Table A1 Outline of SAM (2017-18) constructed for the study

		ACT			COM			FAC		HHD		GOV	S-I	YTX	STX	TAR	ROW	TOT
		OSD	OIL	OTH	OSD	OIL	OTH	LAB	CAP	FAR	OTH							
ACT	OSD					X												
	OIL																	
	OTH																	
COM	OSD		X							X		X	X				X	
	OIL																	
	OTH																	
FAC	LAB		X															
	CAP																	
HHD	FAR							X				X					X	
	OTH																	
GOV															X		X	
S-I										X		X					X	
YTX																		
STX						X												
TAR																		
ROW																		
TOT																		

Note ACT=activities; COM=commodities; FAC=factors; HHD=households; GOV=government; S-I=savings/investment; YTX=income tax; STX=sales tax; TAR=tariff; ROW=rest of the world; OSD=oilseeds; OIL=edible oils; LAB=labor; CAP=capital; FAR=farmers; OTH=others; TOT=total

Table A2 Equations solved in the CGE model

Import price

$$PM_c = (1 + tm_c).EXR\,pwm_c \qquad c \in CM$$

$$\begin{bmatrix} import \\ price \\ (dom.\ cur.) \end{bmatrix} = \begin{bmatrix} tariff \\ adjust- \\ ment \end{bmatrix} . \begin{bmatrix} exchange\ rate \\ (dom.cur.per \\ unit\ of\ \ for.cur.) \end{bmatrix} . \begin{bmatrix} import \\ price \\ (for.cur.) \end{bmatrix}$$

Export price

$$PE_c = (1 - te_c).EXR.pwm_c \qquad c \in CE$$

$$\begin{bmatrix} export \\ price \\ (dom.\ cur.) \end{bmatrix} = \begin{bmatrix} tariff \\ adjust- \\ ment \end{bmatrix} . \begin{bmatrix} exchange\ rate \\ (dom.cur.per \\ unit\ of\ \ for.cur.) \end{bmatrix} . \begin{bmatrix} export \\ price \\ (for.cur.) \end{bmatrix}$$

Absorption

$$PQ_c.QQ = \left[PD_c.QD_c + (PM_c.QM_c)_{|c \in CM|} \right].(1 + tq_c) \qquad c \in C$$

$$[absorption] = \left(\begin{bmatrix} domestic\ sales\ price \\ times \\ domestic\ sales\ quantity \end{bmatrix} + \begin{bmatrix} import\ price \\ times \\ import\ quantity \end{bmatrix} \right) . \begin{bmatrix} sales\ tax \\ adjustment \end{bmatrix}$$

Domestic output value

$$PX_c.QX_c = PD_c.QD_c + (PE_c.QE_c)_{|c \in CE} \qquad c \in C$$

$$\begin{bmatrix} producer \\ price \\ times \\ domestic \\ output\ quantity \end{bmatrix} = \begin{bmatrix} domestic \\ sales\ price \\ times \\ domestic \\ sales\ quantity \end{bmatrix} + \begin{bmatrix} export \\ price \\ times \\ export \\ quantity \end{bmatrix}$$

Activity price

$$PA_a = \sum_{c \in C} PX_c.\theta_{ac} \qquad a \in A$$

$$\begin{bmatrix} activity \\ price \end{bmatrix} = \begin{bmatrix} producer\ prices \\ times\ yields \end{bmatrix}$$

Value-added prices

$$PVA_a = PA_a - \sum_{c \in C} PQ_c\ .\ ica_{ca} \qquad a \in A$$

$$\begin{bmatrix} value \\ added \\ price \end{bmatrix} = \begin{bmatrix} activity \\ price \end{bmatrix} = \begin{bmatrix} input\ \cos t \\ per\ activity \\ unit \end{bmatrix}$$

Activity production function

$$QA_a = ad_a \cdot \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \qquad a \in A$$

$$\begin{bmatrix} activity \\ level \end{bmatrix} = f \begin{bmatrix} factor \\ inputs \end{bmatrix}$$

Factor demand

$$WF_f \,.WFDIST_{fa} = \frac{a_{fa}\,.PVA_a\,.QA_a}{QF_{fa}} \qquad f \in F, a \in A$$

$$\begin{bmatrix} m\arg inal\ \cos t \\ of\ factor\ f \\ in\ activity\ a \end{bmatrix} = \begin{bmatrix} m\arg inal\ revenue \\ product\ of\ factor \\ f\ in\ activity\ a \end{bmatrix}$$

Intermediate demand

$$QINT_{ca} = ica_{ca}\,.\,QA_a \qquad c \in C,\ a \in A$$

$$\begin{bmatrix} \text{int}\,er - \\ mediate \\ demand \end{bmatrix} = f \begin{bmatrix} activity \\ level \end{bmatrix}$$

Output function

$$QX_c = \sum \theta_{ac}\,.QA_a \qquad c \in C$$

$$\begin{bmatrix} domestic \\ output \end{bmatrix} = f \begin{bmatrix} activity \\ level \end{bmatrix}$$

Composite Supply (Armington) Function

$$QQ_c = aq_c \cdot \left(\delta_c^q\,.QM_c^{-\rho_c^q} + (1-\delta_c^q)\,.QD_c^{-\rho_c^q}\right)\rho_c^{\frac{-1}{q}} \qquad c \in CM$$

$$\begin{bmatrix} composite \\ supply \end{bmatrix} = f \begin{bmatrix} import\ quantity,\ domestic \\ use\ of\ domestic\ output \end{bmatrix}$$

Import domestic demand ration

$$\frac{QM_c}{QD_c} = \left(\frac{PD_c}{PM_c} \cdot \frac{\delta_c^q}{1-\delta_c^q}\right)^{\frac{1}{1-\rho_c^q}} \qquad c \in CM$$

$$\begin{bmatrix} import - \\ domestic \\ demand\ ratio \end{bmatrix} = f \begin{bmatrix} domestic - \\ import \\ price\ ratio \end{bmatrix}$$

Composite supply for non-imported commodities

$$QQ_c = QD_c \qquad c \in CNM$$

$$\begin{bmatrix} composite \\ supply \end{bmatrix} = \begin{bmatrix} domestic\ use\ of \\ domestic\ supply \end{bmatrix}$$

Output Transformation (CET) function

$$QX_c = at_c \cdot \left(\delta_c^t . QE_c^{\rho_c^t} + (1-\delta_c^t) . QD_c^{\rho_c^t}\right)\rho_c^{1/t} \qquad c \in CE$$

$$\begin{bmatrix} composite \\ output \end{bmatrix} = f \begin{bmatrix} export\ quantity,\ domestic \\ use\ of\ domestic\ output \end{bmatrix}$$

Export Domestic Supply Ratio

$$\frac{QE_c}{QD_c} = at_c \cdot \left(\frac{PE_c}{PD_c} . \frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^t - 1}} \qquad c \in CE$$

$$\begin{bmatrix} export \\ domestic \\ supply\ ratio \end{bmatrix} = f \begin{bmatrix} export \\ domestic \\ supply\ ratio \end{bmatrix}$$

Output Transformation for Non-Exported Commodities

$$QX_c = QD_c \qquad c \in CNE$$

$$\begin{bmatrix} domestic \\ output \end{bmatrix} = \begin{bmatrix} domestic\ sales\ of \\ domestic\ output \end{bmatrix}$$

Factor Income

$$YF_{hf} = shry_{hf} \cdot \sum_{a \in A} WF_f . WFDIST_{fa} . QF_{fa} \qquad h \in H, f \in F$$

$$\begin{bmatrix} household \\ factor \\ income \end{bmatrix} = \begin{bmatrix} income \\ share\ to \\ household\ h \end{bmatrix} . \begin{bmatrix} factor \\ income \end{bmatrix}$$

Household Income

$$YF_h = \sum_{f \in F} YF_{hf} + tr_{h,gov} + EXR . tr_{h,gov} \qquad h \in H$$

$$\begin{bmatrix} household \\ income \end{bmatrix} = \begin{bmatrix} factor \\ incomes \end{bmatrix} + \begin{bmatrix} transfers\ from \\ governmnets\ \& \\ rest\ of\ world \end{bmatrix}$$

Household Consumption Demand

$$QH_{ch} = \frac{\beta_{ch} . (1-mps_h) . (1-ty_h) . YH}{PQ_c} \qquad c \in C, h \in H$$

$$\begin{bmatrix} household \\ demand\ for \\ commodity\ c \end{bmatrix} = f \begin{bmatrix} household\ income, \\ composite\ price \end{bmatrix}$$

Investment Demand

$$QINV_c = \overline{qinv_c}\ .IADJ \qquad c \in C$$

$$\begin{bmatrix} investment \\ demand\ \ for \\ commodity\ c \end{bmatrix} = \begin{bmatrix} base-year\ investment \\ times \\ adjustment\ \ factor \end{bmatrix}$$

Government Revenue

$$YG = \sum_{h \in H} ty_h\ .\ YH_h + EXR\ .\ tr_{gov,row} + \sum_{c \in C} tq_c . (PD_c . QD_c + (PM_c . QM_c)_{|c \in CM})$$
$$+ \sum_{c \in CM} ty_c\ .\ EXR . pwm_c . QM_c + \sum_{c \in CE} te_c . EXR . pwe_c . QE_c$$

$$\begin{bmatrix} govern- \\ ment \\ revenue \end{bmatrix} = \begin{bmatrix} direct \\ taxes \end{bmatrix} + \begin{bmatrix} transfer \\ from \\ RoW \end{bmatrix} + \begin{bmatrix} sales \\ tax \end{bmatrix} + \begin{bmatrix} import \\ tariffs \end{bmatrix} + \begin{bmatrix} export \\ taxes \end{bmatrix}$$

Government Expenditure

$$EG = \sum_{h \in H} tr_{h,gov} + \sum_{c \in C} PQ_c . qg_c$$

$$\begin{bmatrix} government \\ spending \end{bmatrix} = \begin{bmatrix} household \\ transfers \end{bmatrix} = \begin{bmatrix} government \\ consumption \end{bmatrix}$$

Factor Markets

$$\sum_{a \in A} QF_{fa} = QFS_f \qquad f \in F$$

$$\begin{bmatrix} demand \\ for \\ factor\ f \end{bmatrix} = \begin{bmatrix} supply\ of \\ factor\ \ f \end{bmatrix}$$

Composite commodity market

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + qg_c + QINV_c \qquad c \in C$$

$$\begin{bmatrix} composite \\ supply \end{bmatrix} = \begin{bmatrix} composite\ demand; \\ sum\ \ of\ \ intermediate, \\ household,\ government, \\ \&\ investent\ \ demand \end{bmatrix}$$

Current Account Balance for Rest of the World (in Foreign Currency)

$$\sum pwe_c . QE_c + \sum_{i \in I} tr_{i,row} + FSAV = \sum_{c \in CM} pwm_c . QM_c$$

$$\begin{bmatrix} export \\ revenue \end{bmatrix} = \begin{bmatrix} transfers \\ from \\ RoW \\ to\ households \\ \&\ government \end{bmatrix} = \begin{bmatrix} foreign \\ savings \end{bmatrix} = \begin{bmatrix} import \\ spending \end{bmatrix}$$

Saving – Investment Balance

$$\sum_{h\in H} mps_h \,.\, (1-ty_h)\,.\, YH_h + (YG - EG) + EXR\,.\,FSAV$$
$$= \sum_{c\in C} PQ_c \,.\, QINV_c + WALRAS$$

$$\begin{bmatrix} household \\ savings \end{bmatrix} + \begin{bmatrix} government \\ savings \end{bmatrix} + \begin{bmatrix} foreign \\ savings \end{bmatrix} = \begin{bmatrix} investment \\ spending \end{bmatrix} + \begin{bmatrix} WALRAS \\ dummy \\ variable \end{bmatrix}$$

Price Normalization

$$\sum_{c\in C} PQ_c \,.\, cwts_c = cpi$$

$$\begin{bmatrix} price\ times \\ weights \end{bmatrix} = [CPI]$$

Source Lofgren (2003)

Method A1: Estimating TFP growth using Malmquist Productivity Change Index (MPI)

The output-oriented Malmquist productivity change index based on period t and t+1 technology are respectively defined as:

$$M_t = \frac{D_t(x_{t+1,}\ y_{t+1})}{D_t(x_t,\ y_t)} \quad \text{.........} \ (1)$$

$$M_{t+1} = \frac{D_{t+1}(x_{t+1,}\ y_{t+1})}{D_{t+1}(x_t,\ y_t)} \quad \text{.........} \ (2)$$

Malmquist TFP index measures the change in TFP between two data points by computing the ratio of the distances of each data point relative to constant returns to scale (a common technology) Färe et al. (1994). Equation (3) presents the output-orientated Malmquist TFP change index. In the equation, technology in period t is used as reference technology in the first term while the technology of period t+1 is used as reference technology in the second term inside the bracket. A value of index more than one will indicate progress in TFP from period t to period 1 + t while a value less than one indicates a TFP regress.

$$M = [\frac{D_{t+1}(x_{t+1,}\ y_{t+1})}{D_{t+1}(x_t,\ y_t)} X \frac{D_{t+1}(x_{t+1,}\ y_{t+1})}{D_{t+1}(x_{t,}\ y_t)}]^{1/2} \quad \text{.........} \ (3)$$

The output-oriented Malmquist productivity is a measure of productivity growth (Caves et al., 1982). The above Malmquist equation is decomposed into two components namely efficiency change which captures the performance relative to the best practice in the sample and can be interpreted as the catching-up effect and the technical change which measures the shift in the frontier over time. The decomposition of the above equation is given in equation (4)

$$M = \frac{D_{t+1}(x_{t+1,}\ y_{t+1})}{D_t(x_t,\ y_t)} [\frac{D_t(x_{t+1,}\ y_{t+1})}{D_{t+1}(x_{t+1,}\ y_{t+1})} X \frac{D_t(x_{t,}\ y_t)}{D_{t+1}(x_{t,}\ y_t)}]^{1/2} \quad \text{.........} \ (4)$$

From the equation above, the ratio outside the square brackets measures the change in technical efficiency in period t+1 relative to period t, The efficiency change part tries to compare the distances of two observations (x_t, y_t) and (x_{t+1}, y_{t+1}) to the corresponding production frontiers. It gives information on whether production is catching up with or falling behind the production frontier with the assumption that the component captures diffusion of technology related to differences in innovation and institutional setting. The part inside the bracket (the geometric mean of the two ratios inside the square brackets) captures the shift in technology between the two periods, evaluated at (x_i, y_i) and (x_{i+1}, y_{i+1}).

The distance functions components in equation (4) can be calculated using two techniques known as parametric and non-parametric techniques. In this paper, a non-parametric technique to construct the Malmquist TFP index is utilized. Given the panel data set, we calculate the required distance measures for the Malmquist TFP index using DEA-like linear programs. For each state, four (4) distance functions must be calculated to measure the productivity change between two periods, t and t+1. This requires the solving of four linear programming (LP) problems assuming constant returns to scale (CRS) technology:

$$\begin{aligned} &[D_t(x_t, y_t)]^{-1}) = Max_{\phi,\gamma}\varphi \\ &\textit{subject to} \\ &Y_t >= \theta\, y_{it} \\ &x_{it} >= \theta\, X_t \lambda \\ &\lambda >= 0 \end{aligned} \quad \text{.........} \ (5)$$

$$\begin{aligned} &[D_{t+1}(x_{t+1}, y_{t+1})]^{-1}) = Max_{\phi,\gamma}\varphi \\ &\textit{subject to} \\ &Y_{t+1} >= \theta\, y_{it+1} \\ &x_{it+1} >= \theta\, X_{t+1} \lambda \\ &\lambda >= 0 \end{aligned} \quad \text{.........} \ (6)$$

$$
\begin{aligned}
&[D_t(x_{t+1}, y_{t+1})]^{-1}) = Max_{\phi,\gamma}\varphi \\
&\textit{subject to} \\
&Y_t >= \theta\, y_{it+1} \\
&x_{it+1} >= \theta\, X_t \lambda \\
&\lambda >= 0
\end{aligned}
\qquad \text{......... (7)}
$$

$$
\begin{aligned}
&[D_{t+1}(x_t, y_t)]^{-1}) = Max_{\phi,\gamma}\varphi \\
&\textit{subject to} \\
&Y_{t+1} >= \theta\, y_{it} \\
&x_{it} >= \theta\, X_{t+1} \lambda \\
&\lambda >= 0
\end{aligned}
\qquad \text{......... (8)}
$$

where is a vector of output quantity for the i^{th} entity given as *M x 1*; is a vector of input quantities for the i^{th} entity denoted as *K x 1*; *Y* is a matrix of output quantities for all *N* countries written as *N x M*; *X* is a matrix of input quantities for all *N* countries given as *N x K*; λ is an $N\times 1$ vector of weights, and φ is a scalar. The analysis involved the application of a non-parametric approach which includes both the multi-stage and Malmquist DEA Models to determine the efficiency and productivity change of each entity.

Table A3 Yield and input growth in oilseeds (All-India, 2004-05 –*vs*- 2017-18)

Output/inputs	Groundnut		Sesamum		Soybean		Rapeseed & Mustard		Sunflower	
	2004-05	2017-18	2004-05	2017-18	2004-05	2017-18	2004-05	2017-18	2004-05	2017-18
Yield (qtl/ha)	10.80	13.90	3.23	4.88	11.71	10.96	10.54	14.06	6.51	7.69
Seed (kg/ha)	101.83	116.75	5.69	5.74	97.94	90.11	6.29	6.38	6.62	8.64
Fertilizer (kg/ha)	68.52	118.40	19.08	47.73	53.99	70.38	78.92	115.34	66.93	57.49
Manure (qtl/ha)	22.96	12.35	4.12	6.84	2.42	2.68	6.47	1.56	1.44	0.22
Human labor (man-hrs/ha)	733.67	603.46	353.33	392.82	442.01	237.51	383.87	335.30	345.42	310.24
Animal labor (pair-hrs/ha)	53.03	28.42	36.40	8.65	63.04	14.79	56.32	10.34	65.53	27.90
Machine power (Rs/ha)	2043.99	3913.55	1321.22	2489.68	2104.84	4432.20	2736.22	3479.36	1042.91	2116.31
Insecticides (Rs/ha)	282.2	683.0	66.6	278.8	66.6	1136.1	96.0	204.8	52.2	116.5
Irrigation charges (Rs/ha)	1029.45	917.09	274.99	749.78	274.99	52.60	1901.74	1611.35	1170.75	71.46

Source Cost of Cultivation data
Note Estimates are the states' averages reported in the cost-of-cultivation data; expenditures are in real terms (constant 2011-12 prices)

Table A4 Selected characteristics in edible oil processing sector (2013-14 –vs- 2017-18)

	2013-14	2017-18	Growth (% p.a.)
Gross Value Added (Rs. billion)	63.34	64.62	0.50
Gross capital formation (Rs. billion)	25.81	47.38	20.89
Wages and salaries (Rs. billion)	13.02	16.66	7.00
Persons employed (million)	0.11	0.11	-0.60
Inputs consumed (Rs. billion)	1354.38	1280.71	-1.36
Income (Rs. billion)	40.69	44.87	2.57
Profit (Rs. billion)	26.21	29.53	3.16

Source Annual Survey of Industries

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Measuring farmers' welfare: an analysis across states of India

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Abstract Development literature is replete with comparative studies on the patterns of regional agricultural development and the factors responsible for the regional disparities. Their focus has been on production. However, in recent decades, a paradigm shift has happened away from production to farmers' income, and further to farmers' welfare. This paper identifies multiple indicators of farmers' welfare grouped into (i) production, (ii) post-production, (iii) infrastructure, (iv) social development, (v) ecological aspects, and (vi) policy and fiscal environment, and constructs an index of farmers' welfare for each of the states. Accordingly, we find Punjab ranking the highest and Rajasthan is at the bottom of the index.

Keywords Regional disparity, farmers' welfare index, indicators

JEL Codes Q10, Q13, Q18

Inter-regional variation in economic development is an interesting discourse in the comparative development literature to understand what renders some regions higher on the development continuum and not the others. In India, several studies have explored inter-state variation in agricultural development indicators following different frameworks. A few of them constructed an index to capture a composite view of the inter-state variation in the socio-economic development. NITI Aayog is engaged in evolving an 'Agriculture Transformation Index', for measuring the performance of states across six pillars: (i) inputs (ii) sustainability (iii) productivity and diversification (iv) policy (v) preservation, processing and exports (vi) farmers' income and welfare. Most of these studies have looked at the output and/or input indicators. This approach leaves out certain crucial dimensions because of the changes in policy stance from production to income augmentation, as is reflected in the goal of doubling the farmers' income by 2022. Farmers' Welfare Index can capture the new policy paradigm—at the core of which are the sustainable intensification and increasing farmers' income. Income is an indicator of farmers' welfare, but there are also other dimensions of it. This paper proposes to adopt a farmers' welfare framework to study agricultural development across states. For this purpose, we adapted and extended the concept of farmers' welfare as elaborated in Dalwai (2019).

The remaining paper is organised into different sections elaborating on the concept of farmers' welfare, its dimensions and the indicators, and examining inter-state variation in pre-production and post-production factors; infrastructure -physical, financial and social; policy and fiscal aspects; and ecological factors. State-wise composite Farmers' Welfare Index (FaWI) is discussed in penultimate section followed by conclusions.

Methodology and data

Analytical framework

Dalwai (2019) has listed the following indicators that can reflect farmers' welfare:

- both absolute and relative average income;
- availability and accessibility to social security system – education, health, etc.;
- facilitating the farmer in moving up Maslow's need hierarchy beyond social security

This paper proposes to adopt the farmers' welfare framework in terms of six dimensions viz. (i) production (ii) post-production (iii) infrastructure (iv) social development (v) ecological aspects and (vi) policy & fiscal environment. Production and post-production factors, that can enhance or diminish the welfare of farmers, can include input availability, costs and quality, labour availability and wage rates, output prices, market access, post-harvest facilities, etc. The backward and forward linkages will be more effective if the physical and financial infrastructure such as connectivity, irrigation, power, banking network and penetration, among others are made available to farmers' households. Social infrastructure such as education and health facilities, a network of community organisations, the degree of social capital built up, and so on further add up to the farmers' welfare. Superimposed on these four dimensions are the policy environment and ecological factors that may impact the level of farmers' welfare. Accordingly, we compiled data on various indicators on these six dimensions to understand the level of farmers' welfare across states. We combined these indicators into dimensional indices and then a state-wise composite index of farmers' welfare was worked out. All these indicators are defined such that the higher the value, the higher the farmers' welfare.

We have tried to capture all such dimensions which may influence the state of farmers' welfare (Figure 1). Ranging from the aspects which influence the income outcome such as input availability, government support in marketing and processing to the aspects which may improve productivity like education and health. Availability of good infrastructure facilities like roads and banking that increases the credit absorption capacity, the productivity of inputs along with availability and access to such inputs have also been captured. This aspect is duly incorporated in the framework along with government support under the policy and fiscal environment.

We have identified 90 indicators along the above 6 dimensions and these are listed in Table 1.

The indicators are combined to form dimension indices which, in turn, are combined to construct FaWI. The values of all indicators are normalized to scale down values of indicators between 0 and 1 using the following formula.

$$D_n = (A_n - m)/(M-m) \qquad \ldots(1)$$

Where for n^{th} state D_n is the normalized value of the indicator, A_n is the actual value of the indicator, M is the maximum value of the indicator, and m is the minimum value of the indicator.

Indicators are combined to calculate individual dimension indices as

$$P_{n=} (\Sigma w_i * P_i) \qquad \ldots(2)$$

$$O_{n=} (\Sigma w_j * O_i) \qquad \ldots(3)$$

$$I_n = (\Sigma w_i * I_i) \qquad \ldots(4)$$

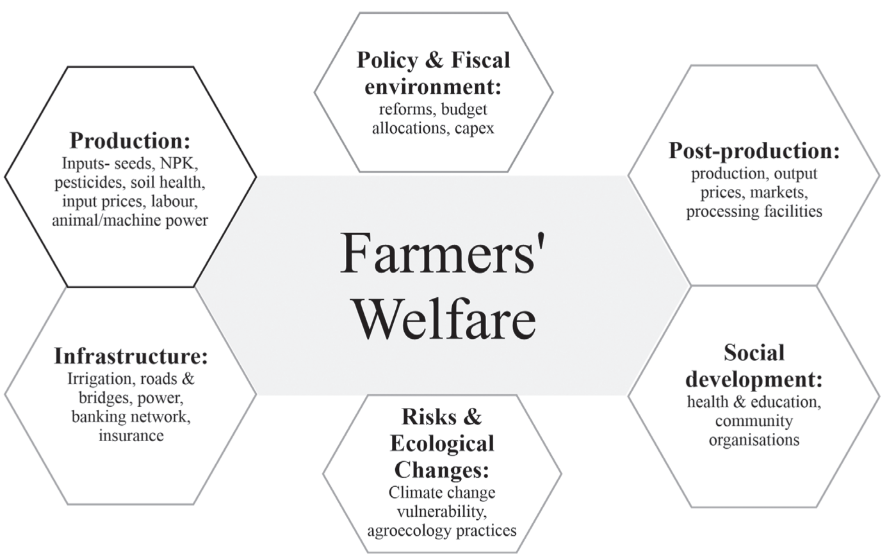

Figure 1 Framework for understanding farmers' welfare

Table 1 Indicators used for constructing FaWI

Dimension	Indicator	Symbol of the indicator	Weight
Production (P)	Number of Soil Health Cards per hectare of Net Sown Area	P1	0.33
	EPWRF Agriculture Index (covering 10 indicators viz. sectoral GVA, pump-sets, energy consumption, etc.)[1]	P2	0.33
	EPWRF Irrigation Index (covering 2 indicators)[1]	P3	0.33
Post-Production (O)	Average monthly agricultural household income from NAFIS survey	O1	0.25
	The ratio of average monthly agricultural household income to non-agricultural household income	O2	0.25
	Total rural primary and wholesale markets per lakh ha of GCA	O3	0.25
	Number of registered/un-incorporated processing units per million value of production	O4	0.25
Physical Infrastructure (I)	Agriculture credit/ha (Rs lakh)	I1	0.143
	Rural branches per one lakh operational holdings	I2	0.143
	NAFINDEX (financial inclusion index covering 18 indicators related to banking products, services and payment mechanisms)[2]	I3	0.143
	Electricity consumption per ha of NSA	I4	0.143
	Electrification index (EPWRF) (covering 3 indicators)[1]	I5	0.143
	Road connectivity index (EPWRF) (covering 1 indicator)[1]	I6	0.143
	Telecommunication index (EPWRF) (covering 1 indicator)[1]	I7	0.143
Social development (S)[1]	EPWRF health index (covering 20 indicators)	S1	0.33
	EPWRF education index (covering 16 indicators)	S2	0.33
	EPWRF drinking water, sanitation and housing index (covering 8 indicators)	S3	0.33
Risks & Ecological Changes (E)	Tree cover and forest cover as % of geographical area	E1	0.50
	Percentage of non-degraded land over total land area	E2	0.50
Policy & Fiscal environment (F)	Public expenditure/operational holding (Rs 000)	F1	1

[1]All these Indices are taken from EPWRF (2021).
[2]Index is taken from Satyasai and Kumar (2020).

$S_{n=} (\Sigma w_i * S_i)$ …(4)

$E_{n=} (\Sigma w_i * E_i)$ …(5)

$F_{n=} (\Sigma w_i * F_i)$ …(6)

Where *i* stands for indicator, *n* stands for each state and *w* stands for the weight assigned to each indicator. All the dimension indices are combined with equal weights to compute FaWI as below:

$FaWI = P_n + O_n + I_n + S_n + E_n + F_n$ …(7)

Data

The data on various indicators have been collected from various sources: Ministry of Agriculture and Farmers' Welfare, GoI; Dalwai Committee; NABARD All India Financial Inclusion Survey (NAFIS) 2016-17; State and Central Government Departments, etc. Some of the indicators are the dimension indices culled from EPWRF 2021, viz., EPWRF Agriculture Index, EPWRF Health Index, EPWRF Education Index, and EPWRF Drinking Water Sanitation and Housing Index, NAFINDEX.

Results and discussion

Production related factors

Indicators on the production phase and backward

Table 2 State-wise value of indicators included in production dimension

State	Number of soil health cards issued/ha of net sown area	EPWRF irrigation index	EPWRF agri index
Andhra Pradesh	2.3	0.25	0.29
Arunachal Pradesh	0.1	0.06	0.01
Assam	0.6	0.00	0.07
Bihar	2.4	0.50	0.09
Chhattisgarh	1.9	0.14	0.15
Goa	0.3	0.09	0.09
Gujarat	1.3	0.26	0.17
Haryana	2.3	0.89	0.16
Himachal Pradesh	2.4	0.14	0.10
Jharkhand	0.7	0.02	0.07
Karnataka	1.6	0.14	0.21
Kerala	1.5	0.06	0.17
Madhya Pradesh	1.2	0.30	0.10
Maharashtra	1.5	0.08	0.22
Manipur	0.4	0.02	0.03
Meghalaya	1.9	0.22	0.02
Mizoram	0.2	0.04	0.03
Nagaland	0.5	0.09	0.02
Odisha	0.9	0.12	0.13
Punjab	0.6	1.00	0.14
Rajasthan	1.0	0.26	0.09
Sikkim	0.8	0.04	0
Tamil Nadu	2.9	0.35	0.21
Telangana	2.4	0.20	0.24
Tripura	0.9	0.18	0.07
Uttar Pradesh	2.3	0.65	0.12
Uttarakhand	2.3	0.37	0.09
West Bengal	1.6	0.61	0.13

linkages that may influence farmers' welfare cover various factors of production, land, labour and input related aspects (Table 2).

Irrigation plays an important role in deciding the cropping pattern and improving crop yields. Around 78% of fresh water in India is used for agriculture (Gulati 2021) and 48% of the gross cropped area is irrigated. There is a wide disparity in the net irrigated area across states. Assam has only 10% of the net sown area under irrigation while Punjab has 100% of the net sown area under irrigation.

State-wise variation in irrigation is due to the varied geographical conditions in different parts of the country. Rugged mountains, sandy deserts and rocky terrains without aquifers have very poor irrigation facilities, whereas fertile alluvial plains with perennial rivers have higher irrigation intensity. Hence, the highest intensity of irrigation exists in Punjab and Haryana, Western Uttar Pradesh, Bihar, West Bengal and Godavari Krishna Deltas. Haryana and Punjab with nearly 100% irrigated areas have higher irrigation intensity, whereas Assam, Kerala, and Maharashtra, which are rainfed states, are characterised by low irrigation intensity.

There is a wide regional variation in the distribution of soil health cards. While it is very high for southern

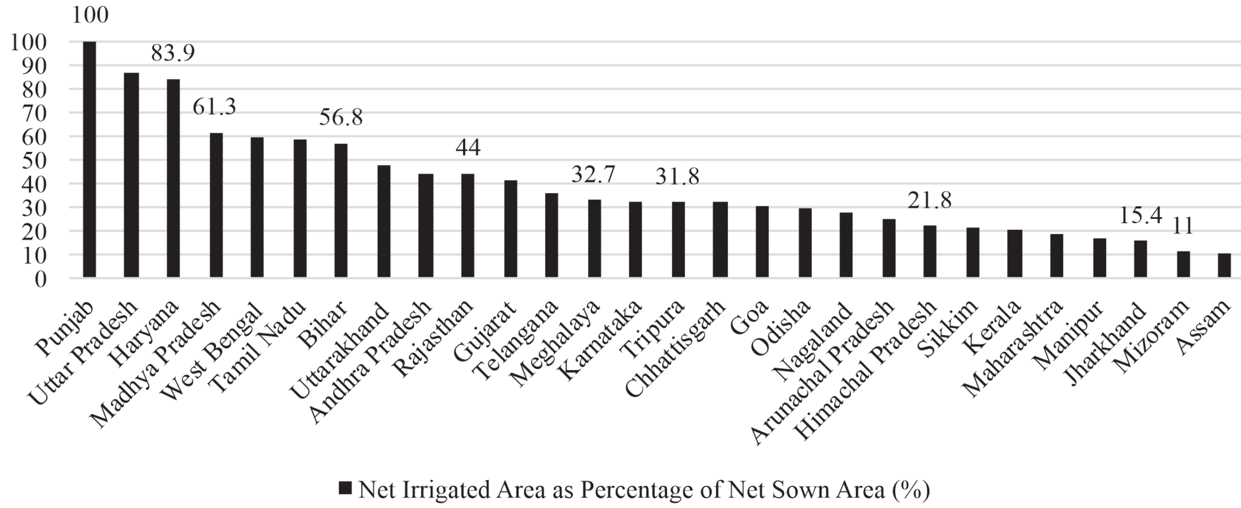

Figure 2 State-wise net irrigated area and net sown area in 2015-16
Source Agriculture Statistics at a Glance, 2019, Directorate of Economics and Statistics, Department of Agriculture Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare.

states (one soil health card per hectare for Tamil Nadu), it stands very low for North-Eastern and Northern states. Punjab which is characterised by the poor health of the soil, had 0.18 soil health cards issued per hectare of net sown area. A high value of SHC/ha of NSA means efficient and effective usage of fertilizers.

Post-production factors

Income is a direct indicator of farmers' welfare, and to compare states on this indicator the state-wise average monthly income per agricultural household as per the NABARD All India Rural Financial Inclusion Survey (NAFIS) 2016-17 has been considered (Table 3). Some of the states like Punjab, Haryana and Kerala have higher average incomes compared to others. It also highlights that the farmers of Bihar, Odisha, Jharkhand, Uttar Pradesh and Madhya Pradesh earn low average monthly income as compared to India's average.

The ratio of agricultural households' income to non-agricultural households' income serves as an important indicator of disparity between agricultural and non-agricultural households (Table 3). The ratio is as high as 2.1 for Punjab and less than 1 for a few states. The higher the ratio, the higher the state ranks in the farmers' welfare index.

Food processing facilities help capture all possible value from food production, bring greater market integration and enable farmers to access assured demand for their produce. This curtails the uncertainty associated with returns from agricultural activity. The higher the processing avenues for primary agri-produce, the better are the chances for a higher share of producers in consumer rupee.

Well-organized marketing infrastructure plays a crucial role in agricultural development, as the marketing system contributes greatly to the monetisation of the farmers' agri-produce (Table 4). An efficient system of price discovery in a market can also act as a catalyst in increasing the farmers' investment for higher productivity and production. The National Commission on Farmers (2007) had recommended that the facility of regulated markets should be available to the farmer within a radius of 5 km. Farmers' income realisation is closely linked to post-production market infrastructure. Small and marginal farmers require good markets nearer to their farms, with robust market linkages.

The total number of rural primary and wholesale markets per lakh hectare of gross cropped area is another indicator of marketing facilities in a state.

Physical and financial infrastructure

Infrastructure acts as an important factor in sustaining the growth of agriculture. This calls for higher Gross Capital Formation (GCF) in agriculture, and also other rural infrastructure including roads, electricity, etc. The condition of rural infrastructure (roads, irrigation and

Table 3 Indicators included in post-production dimension

State	Average monthly income of agricultural household (Ag)	Average monthly income of non-agricultural household (Non-Ag)	Ratio of monthly income of agricultural households/ Income of non-agricultural households	Total rural primary and wholesale markets per lakh ha of GCA	Number of registered/ unincorporated processing units per million value of production
Andhra Pradesh	6920	5296	1.3	4.3	0.2
Arunachal Pradesh	9072	11562	0.8	24.0	0.0
Assam	9878	7985	1.2	27.8	0.2
Bihar	7175	5474	1.3	23.7	0.3
Chhattisgarh	8580	5675	1.5	19.9	0.1
Goa	10687	10760	1.0	17.7	0.3
Gujarat	11899	8617	1.4	2.7	0.1
Haryana	18496	8775	2.1	7.4	0.1
Himachal Pradesh	11828	11402	1.0	8.2	0.2
Jharkhand	6991	4676	1.5	48	0.6
Karnataka	10603	5193	2.0	10.1	0.2
Kerala	16927	14863	1.1	52.1	0.3
Madhya Pradesh	7919	4877	1.6	0	0.1
Maharashtra	10268	8188	1.3	18.8	0.2
Manipur	9861	9435	1.0	31.6	0.2
Meghalaya	10039	10144	1.0	35	0.2
Mizoram	9931	8034	1.2	197.6	0.1
Nagaland	9950	10043	1.0	38.7	0.1
Odisha	7731	6563	1.2	30	0.2
Punjab	23133	10935	2.1	23.1	0.1
Rajasthan	9013	7172	1.3	2.9	0.1
Sikkim	8603	8497	1.0	12.9	0.0
Tamil Nadu	9775	9708	1.0	0	0.4
Telangana	8951	6787	1.3	4.1	0.3
Tripura	7592	9271	0.8	-	0.4
Uttar Pradesh	6668	5565	1.2	15.6	0.2
Uttarakhand	10855	7309	1.5	6	0.2
West Bengal	7756	6383	1.2	36.7	0.3

Table 4 Distribution of states according to market density

Market Density (Area served in sq. km. per regulated market)	States
Less than 100 sq. km.	Nil
101 -200 sq. km.	Punjab, Haryana, WB
201-400 sq. km.	AP, Assam, Maharashtra, Odisha, Karnataka, UP, Jharkhand
601-800 sq. km.	TN, Goa, Gujarat, MP, Chhattisgarh, Rajasthan
801-1000 sq. km.	Uttarakhand, HP

Source Indiastat

electricity) in several states is a matter of serious concern and needs substantial up-gradation for the full realisation of the potential of agricultural growth (Table 5).

With the increasing share of purchased inputs in agriculture, the credit assumes greater importance in augmenting crop yields through the use of high yielding varieties of seeds, fertilizers, pesticides, etc. However, there is a wide inter-state disparity in the availability of agricultural credit. The year-on-year growth is the lowest in the Western, Northern and North-Eastern regions.

Table 5 Indicators included in physical and financial infrastructure dimension

State	Agriculture credit/ha of net sown area (₹ Lakh)	Rural branches per one lakh operational holding	Electricity consumption kWh per ha of NSA	Road connectivity index (EPWRF)	Electrification index (EPWRF)	Tele-communi-cation index	NAFINDEX
Andhra Pradesh	1.81	28.59	1704.5	0.15	0.75	0.12	0.47
Arunachal Pradesh	0.31	68.14	NA	0.01	0.20	0.29	0.36
Assam	0.19	51.35	11.5	0.76	0.39	0.03	0.39
Bihar	0.53	20.65	96.0	0.42	0.24	0.01	0.23
Chhattisgarh	0.27	28.30	893.3	0.04	0.37	0.05	0.09
Goa	0.63	366.67	168.2	0.74	0.11	0.99	0.60
Gujarat	0.62	48.43	1267.0	0.07	0.41	0.17	0.30
Haryana	0.98	102.58	1492.2	0.05	0.91	0.14	0.42
Himachal Pradesh	0.83	122.37	67.5	0.10	0.64	0.37	0.38
Jharkhand	0.30	48.91	116.1	0.06	0.14	0.01	0.30
Karnataka	0.71	41.14	1897.6	0.21	0.70	0.15	0.48
Kerala	3.68	4.81	132.7	0.96	0.72	0.58	0.47
Madhya Pradesh	0.26	23.63	855.4	0.12	0.42	0.04	0.17
Maharashtra	0.35	20.88	1475.1	0.23	0.73	0.14	0.31
Manipur	0.07	60.00	4.8	0.09	0.28	0.04	0.46
Meghalaya	0.07	75.43	NA	0.06	0.39	0.05	0.36
Mizoram	0.09	33.50	NA	0.02	0.52	0.13	0.39
Nagaland	0.06	60.00	NA	0.33	0.47	0.00	0.32
Odisha	0.52	54.79	116.4	0.31	0.48	0.08	0.43
Punjab	1.01	235.22	1431.5	0.34	0.69	0.28	0.49
Rajasthan	0.37	38.42	931.5	0.07	0.72	0.07	0.22
Sikkim	0.13	113.89	NA	0.14	0.59	0.05	0.35
Tamil Nadu	3.71	38.31	2153.0	0.30	0.60	0.34	0.28
Telangana	1.29	26.08	4920.7	0.13	0.98	0.12	0.48
Tripura	0.57	44.50	83.7	0.64	0.64	0.03	0.45
Uttar Pradesh	0.41	33.28	662.6	0.13	0.20	0.02	0.29
Uttarakhand	0.97	109.53	415.7	0.05	0.50	0.10	0.28
West Bengal	0.55	51.84	153.4	0.49	0.61	0.06	0.32

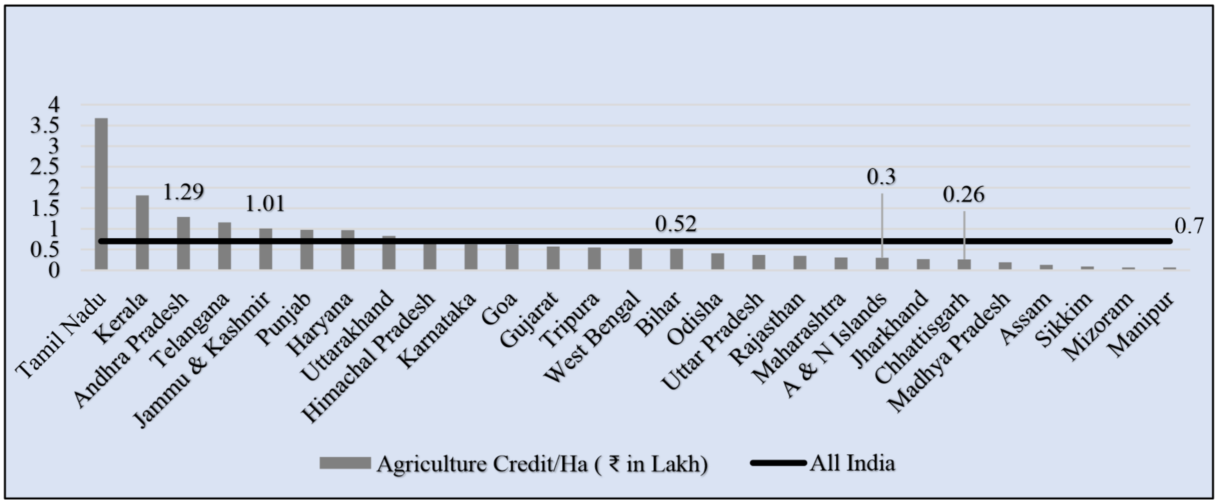

Figure 3 State-wise credit per hectare in 2019-20 (Rs lakh)
Source NABARD

The Southern region has higher credit absorption capacity because of better infrastructure facilities, and better outreach and credit. Normally, the low density of credit delivery outlets and the weak financial health of rural financial institutions could be the constraints for increasing credit flow in credit in the Eastern and Central states (NABARD, 2021).

There is a wide variation in credit per hectare across states. Andhra Pradesh and Punjab have better availability of credit per hectare (Figure 3), and it is less for a larger state like Uttar Pradesh. In this context, the credit absorption capacity of states plays a major role in determining the demand for credit. Tamil Nadu which has the highest credit per hectare also scores high on other indicators like electricity use per hectare and road index. North-Eastern states have very low credit per hectare, and also score low on other indicators of infrastructure.

Road connectivity has the potential to lower input costs, reduce post-harvest losses, and address issues related to the gap between farm-gate price and consumer price. Availability of road network facilitates trade, transportation, social integration and economic development. Poor road connectivity in a state hampers better price realisation, access to marketing avenues and increases the cost of inputs. Hence, it is an important determinant of farmers' welfare.

Agriculture consumes around 20% of the total electricity consumption in the country. However, electricity consumption per hectare varies greatly across states, Telangana 4920 kWh/ha and Bihar 96 kWh/ha (Table 5). The higher electricity consumption per hectare also positively impacts the irrigation levels, although power subsidy leads to inefficient use of power and groundwater extraction leading to alarmingly low levels of groundwater.

NAFINDEX is a multi-dimensional financial inclusion index that has been constructed using three dimensions, traditional banking products, modern banking services, and payment systems. There are variations across states in the value of NAFINDEX and dimension indices. In many states which saw lower penetration of traditional banking products as reflected in the respective dimension index, the modern banking products and payment mechanisms showed higher values. This index acts as a comprehensive indicator for ascertaining the impact of financial infrastructure on farmers' welfare.

Social infrastructure

Access to education and health facilities are central to human wellbeing and happiness. It also makes an important contribution to economic progress, as healthy populations live longer, are more productive, and save more. Education helps in attaining better skills and knowledge leading to higher efficiency and effectiveness.

Table 6 Indicators included in social infrastructure dimension

State	EPWRF Health Index	EPWRF Education Index	EPWRF Drinking Water, Sanitation and Housing Index
Andhra Pradesh	0.48	0.34	0.44
Arunachal Pradesh	0.22	0.32	0.58
Assam	0.38	0.25	0.49
Bihar	0.17	0.24	0.23
Chhattisgarh	0.38	0.34	0.26
Goa	0.57	0.55	0.86
Gujarat	0.33	0.42	0.60
Haryana	0.33	0.64	0.87
Himachal Pradesh	0.37	0.77	0.79
Jharkhand	0.14	0.22	0.05
Karnataka	0.45	0.52	0.54
Kerala	0.47	0.74	0.62
Madhya Pradesh	0.28	0.27	0.18
Maharashtra	0.39	0.46	0.61
Manipur	0.30	0.34	0.59
Meghalaya	0.38	0.10	0.42
Mizoram	0.54	0.46	0.62
Nagaland	0.30	0.34	0.65
Odisha	0.33	0.34	0.05
Punjab	0.50	0.67	0.86
Rajasthan	0.37	0.40	0.42
Sikkim	0.53	0.60	0.97
Tamil Nadu	0.52	0.63	0.40
Telangana	0.46	0.42	0.58
Tripura	0.40	0.35	0.15
Uttar Pradesh	0.26	0.38	0.20
Uttarakhand	0.36	0.67	0.80
West Bengal	0.42	0.29	0.28

The state-wise comparison of education, health and sanitation index brings out interesting insights into the state of farmers' welfare in the states (Table 6). While Tamil Nadu performs exceptionally on the first two indices, it lags behind some states in the drinking water and sanitation index. Haryana scores high on the drinking water, sanitation index and education index but it lags on the health index.

Policy and fiscal ecosystem

Allocations for the agricultural sector have increased significantly over the years, however, much of these are on account of revenue expenditure on development and welfare schemes. It is time to increase allocations for investment in productive capacity; and the priority sectors are research and education, infrastructure

Table 7 State-wise public expenditure on agriculture and allied activities

(Rs crore)

State	2018-19	2019-20	2020-21	Expenditure (2018-19 to 2020-21)/ operational holding (Rs 000)
Andhra Pradesh	8489	6714	6714	8.8
Arunachal Pradesh	800	1178	1079	81.0
Assam	2895	6449	4580	14.9
Bihar	3636	6880	6702	2.9
Chhattisgarh	18020	21470	15607	40.1
Goa	331	536	569	52.8
Gujarat	8367	7785	7778	15.0
Haryana	3392	4409	6045	21.6
Himachal Pradesh	2185	2458	2683	21.5
Jammu & Kashmir	2840	3048	3823	NA
Jharkhand	1788	4229	4585	9.6
Karnataka	20305	21502	15753	21.6
Kerala	6193	6010	6930	7.8
Madhya Pradesh	15603	13233	9579	13.6
Maharashtra	20020	32940	23862	17.2
Manipur	549	875	1113	42.1
Meghalaya	676	1115	1034	34.0
Mizoram	569	709	692	67.5
Nagaland	694	918	895	37.9
Odisha	7843	12104	11554	17.6
Punjab	12343	11777	13193	96.4
Rajasthan	8376	10865	11182	10.6
Sikkim	428	726	611	67.3
Tamil Nadu	12362	14647	15227	16.2
Telangana	12600	21468	25148	22.8
Tripura	733	878	1005	13.2
Uttar Pradesh	12129	10351	11336	7.0
Uttarakhand	2485	2714	3252	27.7
West Bengal	7911	5071	8983	7.7

Source Various issues of state finances: A study of budgets, RBI

development for livestock services, micro-irrigation and land development. During the triennial ending 2019-20 the average expenditure on agriculture and allied sectors per operational holding shows wide variation. States like Bihar, Uttar Pradesh, Kerala, West Bengal, and Andhra Pradesh spend less than Rs96400 per operational holding (Table 7). This inadequate allocation affects the growth of agriculture, income along with private expenditure on investment.

Ecological aspects

Inclusive and sustainable management of natural resources is important for enhancing the farmers'

Table 8 Variation in ecological dimension

State	Tree cover and forest cover as % of Geographical Area	Percentage of non-degraded land in total land area
Andhra Pradesh	0.22	66.19
Arunachal Pradesh	0.26	88.26
Assam	0.27	90.55
Bihar	0.11	87.34
Chhattisgarh	0.41	73.15
Goa	0.82	88.36
Gujarat	0.14	70.00
Haryana	0.01	91.20
Himachal Pradesh	0.20	77.01
Jharkhand	0.36	83.44
Karnataka	0.28	72.52
Kerala	0.77	92.34
Madhya Pradesh	0.29	80.83
Maharashtra	0.26	64.28
Manipur	0.18	61.71
Meghalaya	0.58	71.62
Mizoram	0.47	65.08
Nagaland	0.45	52.95
Odisha	0.35	61.68
Punjab	0.02	96.85
Rajasthan	0.06	47.31
Sikkim	0.06	89.25
Tamil Nadu	0.30	81.24
Telangana	0.20	71.15
Tripura	0.45	90.20
Uttar Pradesh	0.10	89.00
Uttarakhand	0.28	82.32
West Bengal	0.22	94.44

welfare. India is facing a grim situation of desertification and transformation of fertile land into degraded land. The country's Green Revolution pockets are more prone to the problem. The indiscriminate usage of fertilizers, overuse of groundwater and flood irrigation have negatively impacted soil fertility in many states. The percentage of non-degraded land to total area is positively related to farmers' welfare (Table 8). Higher the non-degraded land's share, the higher is the level of farmers' welfare.

Farmers' Welfare Index (FaWI)

In the foregoing sections, inter-state variations in various aspects have been discussed which have bearing on farmers' welfare. In this section, we present a composite index, FaWI combining indicators under six dimensions discussed earlier (Table 9). Farmers' Welfare Index (FaWI) as a composite index of 90 indicators representing six dimensions has a coefficient of variation (CV) of 25% with Punjab at the top with a

Table 9 Farmers' Welfare Index and its dimensions

State	Production	Post-production	Infrastructure	Social development	Ecological dimension	Fiscal dimension	FaWI
Andhra Pradesh	0.47	0.20	0.34	0.42	0.30	0.06	0.30
Arunachal Pradesh	0.07	0.07	0.16	0.37	0.54	0.84	0.34
Assam	0.10	0.26	0.25	0.37	0.57	0.13	0.28
Bihar	0.50	0.26	0.15	0.22	0.46	0.00	0.26
Chhattisgarh	0.34	0.22	0.12	0.33	0.47	0.40	0.31
Goa	0.13	0.22	0.52	0.66	0.82	0.53	0.48
Gujarat	0.31	0.23	0.21	0.45	0.30	0.13	0.27
Haryana	0.62	0.46	0.33	0.61	0.45	0.20	0.45
Himachal Pradesh	0.42	0.23	0.29	0.64	0.40	0.20	0.36
Jharkhand	0.13	0.45	0.10	0.13	0.54	0.07	0.24
Karnataka	0.33	0.39	0.31	0.50	0.39	0.20	0.35
Kerala	0.28	0.40	0.53	0.61	0.84	0.05	0.45
Madhya Pradesh	0.31	0.21	0.15	0.25	0.48	0.11	0.25
Maharashtra	0.31	0.23	0.26	0.49	0.30	0.15	0.29
Manipur	0.05	0.22	0.15	0.41	0.24	0.42	0.25
Meghalaya	0.30	0.20	0.15	0.30	0.53	0.33	0.30
Mizoram	0.05	0.44	0.16	0.54	0.42	0.69	0.38
Nagaland	0.13	0.18	0.18	0.43	0.28	0.37	0.26
Odisha	0.20	0.22	0.22	0.24	0.32	0.16	0.23
Punjab	0.44	0.57	0.42	0.68	0.51	1.00	0.60
Rajasthan	0.27	0.17	0.21	0.40	0.03	0.08	0.19
Sikkim	0.13	0.09	0.21	0.70	0.45	0.69	0.38
Tamil Nadu	0.52	0.24	0.44	0.52	0.49	0.14	0.39
Telangana	0.46	0.24	0.44	0.49	0.34	0.21	0.36
Tripura	0.26	0.17	0.29	0.30	0.66	0.11	0.30
Uttar Pradesh	0.53	0.18	0.14	0.28	0.47	0.04	0.27
Uttarakhand	0.48	0.29	0.22	0.61	0.49	0.27	0.39
West Bengal	0.46	0.28	0.25	0.33	0.58	0.05	0.33

value of 0.60 and Rajasthan at the lower end with a value of 0.19. Among the dimensions, variation in fiscal dimension was maximum with a CV of 94%.

Conclusions

Approximately 70% of the Indians live in rural areas and are mostly engaged in agriculture and allied activities for their livelihood. Although the share of agriculture in the total gross domestic product (GDP) has been declining, the performance of the economy and the standard of living of a large section of the population depends on the growth in the agricultural sector. Therefore, it is imperative to reduce employment pressure on agriculture by improving inter-sectoral market linkages and shifting the labour force from the farm to the non-farm sector. Also, the level of agricultural development varies from region to region. Except for the states of Punjab, Haryana and Western Uttar Pradesh where the green revolution resulted in

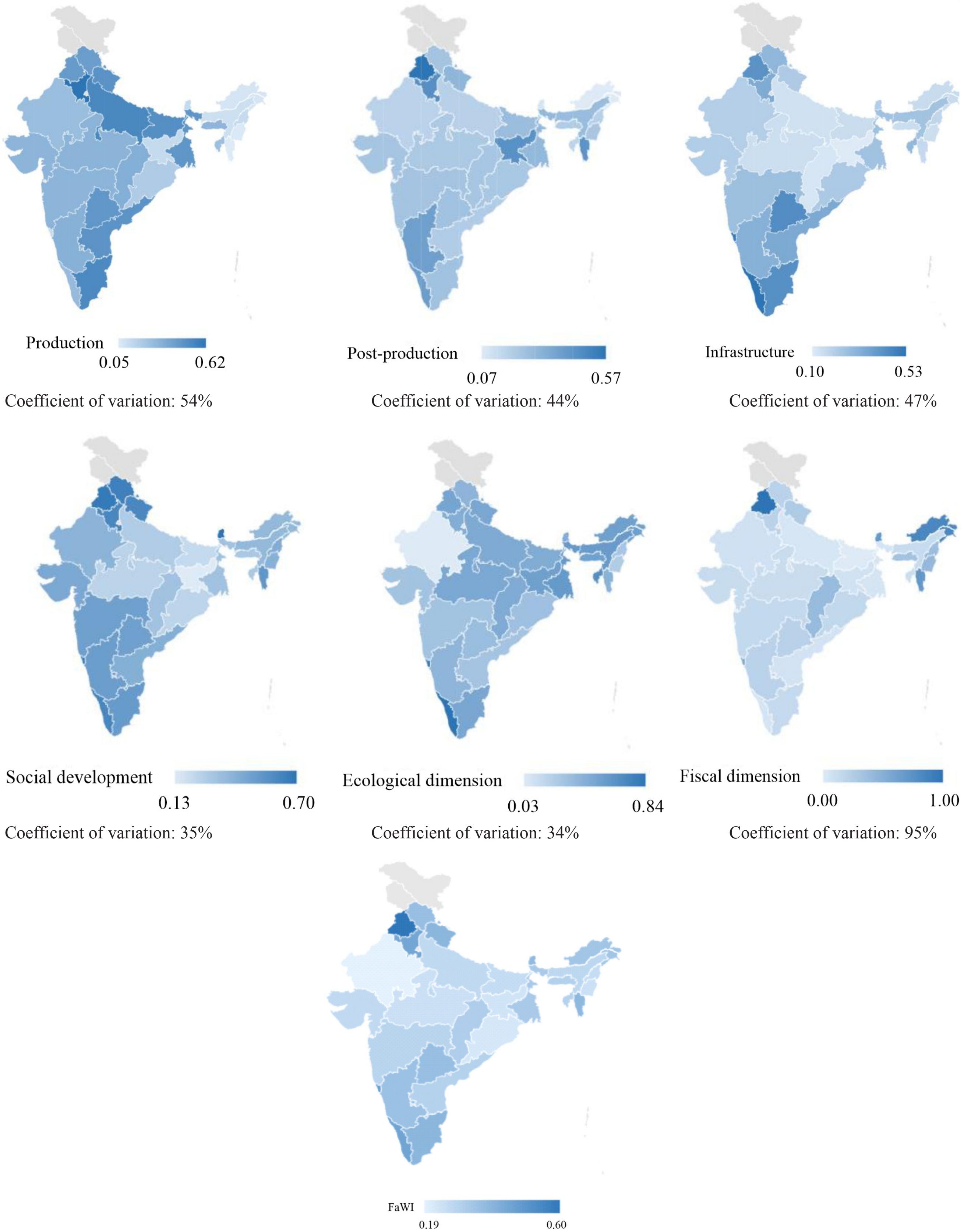

Figure 4 Spatial pattern of Farmers' Welfare Index (FaWI) and its dimensions

higher output mainly for wheat and paddy due to the adoption of technologies, HYV seeds and assured irrigation, most of the states are associated with low levels of agricultural productivity and per capita output. The human capital (rural literacy), physical capital (tractor, pump set and other farm machinery), rural infrastructure (irrigation facilities, rural connectivity, digital connectivity, market facilities, etc.) and access to credit have effects on the growth rates of agricultural development. Hence, higher investment for the creation of infrastructural facilities on the above factors with a special focus on the eastern and North Eastern states could be an effective way of achieving high growth rates and reducing regional disparities in agricultural development.

In this paper, we adopted a farmers' welfare framework and attempted to capture the inter-state variation in agricultural development discussed in the foregoing paragraph from a different paradigm. We constructed a Farmers' Welfare Index (FaWI) as a composite index of 90 indicators representing six dimensions. The results revealed variation (Coefficient of Variation of 25%) in the Index with Punjab at the top with a value of 0.58 and Rajasthan at the lower end with a value of 0.19. Variations in fiscal dimension were maximum with a CV of 94%. This study is expected to spur further debate and encourage more researchers to undertake studies for improvising on the methodology and scope as we move forward.

[The views expressed in the paper are authors' own and other usual disclaimers apply]

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What determines multidimensional poverty among farmers? evidence from the Jagatsinghpur district of Odisha

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Abstract This study assesses the magnitude of multidimensional poverty among the farmers in the Jagatsinghpur district of Odisha and also determines the factor responsible for such a state of affairs. It applies the Alkire-Foster method to find the extent of multidimensional poverty, and OLS regression to determine the factors affecting it. Two-thirds of the farmers have been found either to be multidimensional poor or severe multidimensional poor. Levels of education, size of landholdings, and length of farming experience are found significant in determining multidimensional poverty. Therefore, reorienting government policies for encouraging farmers for higher education, and promoting scientific cultivation through training and skill development can go a long way to eradicate multidimensional poverty.

Keywords Farming, Multidimensional poverty, Alkire-Foster method, MPI, Odisha

JEL Codes I31, I32, I38

People are at the centre of development. Creating an enabling environment in which people can enjoy a long, healthy, and peaceful life is the basic goal of development. People's life satisfaction depends upon the fulfilment of basic facilities like food, cloth, and shelter (Amao, Ayantoye, and Fanifosi 2017, Jaiyeola and Barat 2020), and the inability to meet these basic requirements is known as poverty. Traditionally, poverty has been viewed in a monetary sense caused by the lack of income or expenditure (Fransman and Yu 2019). But, income alone is not enough to address other facets of well-being such as health, happiness, and self-esteem (Khan and Shah 2020, Dagunga, Ayamga, and Danso-Abbeam 2021). Poor always experience several disadvantages such as lack of education, proper health care facilities, lack of access to clean drinking water, and improved sanitation facilities (Tanwar et al. 2019), and hence poverty is treated as a multidimensional phenomenon(Lu, Routray, and Ahmad 2019, Jaiyeola and Bayat 2020).

The global multidimensional poverty index (MPI)was constructed jointly by UNDP and OPHI (Oxford Poverty and Human Development Initiative) by considering three dimensions, viz., education, health, and living standard and ten indicators (Alkire and Santos 2010; Alkire, Roche, and Seth 2013; Alkire, Kanagaratnam and Suppa 2019). Afterwards, other researchers also include all these three dimensions and ten indicators in their multidimensional poverty study(De and Datta 2014, Permanyer and Hussain 2018, Strotmann and Volkert 2018). Considering the importance of the sustainable environment, empowerment of the people as well as their social relationship, other researchers include environment, empowerment, and social connectedness dimension in their multidimensional poverty studies (Biswal, Mishra, and Sarangi 2020, Martinez Jr.and Perales 2017, Nowak and Scheicher 2017, Daraand Ramakrishna 2016, Trani et al. 2016, Vijaya, Lahoti, and Swaminathan 2014, Ataguba, Ichoku, and Fonta 2013, Naveedand Ul-Islam 2010). Although most of the studies relating to multidimensional poverty include completed years of schooling under education dimension; nutritional status of the people under health dimension; housing condition, access to clean drinking water, improved sanitation facility, clean energy, electricity, and ownership of the motor vehicle under the standard of living dimension, some other studies also includes Body Mass Index (BMI) to measure nutritional deficiency (Biswal, Mishra, and Sarangi 2020, Alkire et al. 2020,Ntsalaze and Ikhide 2018, Dara and Ramakrishna 2016, Dehury and Mohanty 2015, Naveed and Ul-Islam 2010), immunization/vaccination of individuals (Hegde et al. 2019, Saleem and Khan 2017), and individuals health insurance (Alkire et al. 2020, Dara and Ramakrishna 2016, Dehury and Mohanty 2015, Angulo, Diaz, and Pardo 2016) under health dimension; possession of bank account (Biswal, Mishra, and Sarangi 2020, Alkire et al. 2020) and land resource (Biswal, Mishra, and Sarangi 2020, Mishra et al. 2020,Vijaya, Lahoti, and Swaminathan 2014, Naveed and Ul-Islam 2010) under the standard of living dimension; individuals practising open defecation (Biswal, Mishra, and Sarangi 2020) and use of dirty cooking fuel (Biswal, Mishra, Sarangi 2020, Alkire and Apablaza 2016, Naveed and Ul-Islam 2010) under environment dimension; autonomy of individual in (i) healthcare decision, (ii) prevention of domestic violence, and (iii) employment choice under empowerment dimension (Biswal, Mishra, and Sarangi 2020, Vijaya, Lahoti, and Swaminathan 2014, Ataguba, Ichoku, and Fonta 2013); and peoples participation and organization of community level activities (Biswal, Mishra, and Sarangi 2020, Martinez Jr. and Perales 2017, Nowak and Scheicher 2017, Trani et al. 2016) under social connectedness dimension. Keeping in view all these dimensions and indicators used by distinct researchers in their studies on multidimensional poverty, the present study includes six dimensions, viz., education, health, living standard, environment, empowerment, and social connectedness, comprising of seventeen indicators to measure the status of multidimensional poverty of farmers.

Poverty is considered simply a rural phenomenon because of its higher concentration in rural areas in comparison to urban areas (Bhutto and Bazmi 2007). The majority of people in the world live in the rural area and depends upon agriculture as their main occupation(Khatiwada et al. 2017) and therefore agriculture is vital from the viewpoint of reducing poverty and hunger (Gassner et al. 2019). Farming is subject to climate risk and uncertainties which stands in the way of sustainable livelihood support to the farmers. Odisha, an eastern state of India, is primarily an agrarian and more than 70% of people are depending upon agriculture for their livelihood (Nanda, Sinha, and Kumar 2011, Pattnaik and Swain 2017). Agriculture in the state is under the vagaries of natural calamities like floods, droughts, cyclones which destroy yield and production in farming (Bahinipati and Sahu 2012, Pattnaik and Swain 2017). This mostly makes the people of the state prone to poverty, starvation, and marginalization (Mishra 2009). Jagatsinghpur is an eastern coastal and agrarian district of Odisha. As per the 2011 Census, this district has a total population of 11,36,971 comprising 5,77,865 males and 5,59,106 females(District Statistical Handbook, Jagatsinghpur 2018). Although agriculture is treated as the backbone of the district, still farmers are living under depressed conditions, stress, and severe deprivations (Moharaj and Rout 2021). The sudden occurrence of natural disasters like floods, cyclones, and drought adversely affects the poorer and socially disadvantaged groups as they are lacking coping abilities (Jena 2018). The status of different sustainable development goals (SDGs) and the multidimensional poverty in Odisha (Table 1) is discussed below.

(i) Continuous increase in the score for composite SDGs from 2018 to 2020 does enable the state to come out of the status of the aspirant and achieve a tag of the performer. The state is achieving an improvement in the health care facilities, access to clean drinking water, improved sanitation facilities, and clean energy as revealed through a continuous increase in the score for SDG 3, SDG 6, and SDG 7 over the period 2018 – 2020.

(ii) The widening gap between the goal and performance in respect of SDG 1 (no poverty) and SDG 10 (reduced inequality) reveals an increase in poverty and inequalities in the state and creates doubt in achieving the tag of an achiever by 2030 in these two goals. The same is also revealed from increased MPI scores in 2019 and 2020 from 2018.

(iii) The score of SDG 8 (decent work and economic growth) has increased during 2018 - 2019 and then decreased in 2020. This uneven pattern reflects a lack of employment opportunities for the people

Table 1 SDGs and multidimensional poverty in Odisha

Parameter		2018 (Score)	2019 (Score)	2020 (Score)
Composite SDG		34	58	61
SDG – 1	No Poverty	59	47	41
SDG – 2	Zero Hunger	46	34	42
SDG – 3	Good Health & Well-Being	54	61	67
SDG – 4	Quality Education	46	40	45
SDG – 5	Gender Equality	43	35	46
SDG – 6	Clean Water & Sanitation	43	85	86
SDG – 7	Clean Energy	23	50	80
SDG – 8	Decent Work	53	59	48
SDG – 10	Reduced Inequalities	78	69	66
	MPI	0.154	0.156	0.156
	0-49 = Aspirant	50-64 = Performer	65-99 = Front Runner	100 = Achiever

Note MPI = Multidimensional Poverty Index, SDG = Sustainable Development Goal

Source Authors' compilation from the data retrieved from https://ophi.org.uk/multidimensional-poverty-index/data-tables-do-files/and http://niti.gov.in/reports-sdg

that leads to a low level of income and the presence of widespread poverty in the state.

(iv) The irregular pattern of the score of SDG 2 (zero hunger), SDG 4 (quality education), and SDG 5 (gender equality) in the state over the period 2018 to 2020 illustrates the nutritional deficiency of the people, the prevalence of adult illiteracy, lack of equitable primary education, and gender discrimination reflected through the lack of equal opportunities for women in decision-making, ownership, and control over economic resources, which are responsible for the presence of multidimensional poverty.

Against this backdrop, we have studied the status and determinants of multidimensional poverty among the farmers in the Jagatsinghpur district of Odisha. Specifically, the objectives of this study are:(i) to measure the magnitude of multidimensional poverty among the farmers, and (ii) to explore the determinants of multidimensional poverty among the farmers. For this purpose, we have used Alkire and Foster (2011) method to construct MPI to assess the extent of multidimensional poverty among the farmers in the Jagatsinghpur district of Odisha. Furthermore, we have used OLS based dummy variable regression to determine the factors responsible for the multidimensional poverty among the farmers in the Jagatsinghpur district of Odisha. This study contributes to the literature the evidence that 2/3rd of the farmers in the Jagatsinghpur district of Odisha are either multidimensionally poor or severely multi-dimensionally poor. The empirical evidence also suggests that the levels of education, size of land holdings, and the length of farming experience significantly determines the extent of multidimensional poverty among farmers in the Jagatsinghpur district. This study is of the first of its kind in the context of Odisha, and thus, the novelty of the study is justified. The remaining of the article is structured as follows: Section 2 reviews the relevant literature, section 3 discusses the data and methodology used in the study, section 4 discusses the results, and section 5 makes the concluding remarks.

Literature review

Poverty has many manifestations such as unemployment, indebtedness, lack of freedom, and inability to afford basic needs (Olarinde et al. 2020). Many of the World's poor are small farm holders who depend on agriculture for their food, income, and employment (De Janvry and Sadoulet 2009). Uncertainty of rainfall, pest attacks, fire outbreaks, changes in soil condition, and social conflicts affect the farmers' agricultural productivity and are considered to be the key factors accountable for making farmers poor (Olarinde et al. 2020). Cerio et al. (2019), in their study on multidimensional poverty, observed that three fourth of farm households were multidimensionally poor due to less scope for generating income from their farm holdings. Although typically small farm holders are poorer, because of the commercialization of agricultural products they can increase their income and improve the standard of living and thereby capable of reducing both incomes as well as multidimensional poverty (Ogutu, Ochieng, and Qaim 2020, Ogutu and Qaim 2019). Parent's education, age, family income, landholding, and livelihood diversification are key factors responsible for multidimensional child poverty in rural farm households of Meghalaya, where most of the children of the household were deprived of safe drinking water, clean cooking fuel, and necessary housing conditions (Hegde et al. 2019). The dynamics of poverty are observed in a multidimensional spectrum across agro-climatic zones of Punjab Province, encompassing both economic and noneconomic dimensions such as health, education, income, and housing services. The study observed that a high level of deprivation was found in education and housing services due to people's unwillingness towards taking higher education (Khan and Shah 2020).

Agriculture is the backbone of Odisha as the majority of people depend on it for their livelihood and sustenance. But the growth in agricultural production is not encouraging due to the shift of people's interest from agriculture to the non-farm sector (Sahoo 2015). Poverty is highly prevalent in Odisha because the landholding pattern is skewed in favour of large farmers. Small and landless farmers are the worst sufferer due to low assets and other facilities (Nanda, Sinha, and Kumar 2011). Farmers in the state suffering from poverty due to climate change face loss in the crop yield (Sharma, Reddy, and Sahu 2014, Padhi and Nayak 2012). The regular occurrence of the cyclone resulting low level of production is the main cause for aggravating the situation of poverty in coastal Odisha (Bahinipati and Sahu 2012). Small and marginal farmers in the state are facing lots of difficulties in selling their agricultural products at a remunerative price and live under distressed conditions (Panda 2017). In this context, multidimensional poverty study among farmers in an agrarian state like Odisha is highly significant for academicians, researchers, and policy planners.

Materials and methods

Jagatsinghpur, the coastal agrarian district of Odisha, constitutes eight blocks, 1292 villages, and 2,33,626 rural households (Census of India, 2011)[1]. Multistage random sampling technique was used to select sample households for the collection of primary data. The field survey was conducted between January – March 2021. Raosoft online sample size calculator was used to determine the size of sample households, i.e., 384 households with 95%confidence level and 5% margin of error for the whole Jagatsinghpur district. In the first stage, sixteen villages were selected randomly, two from each block and in the second stage, sample households were selected randomly from each selected village with equal proportion to sample households under the respective block (Table 2). SPSS-22 was used to select both the sample village and household randomly. Finally, all the individual farmers (208 in number) in the age group of 18 years and older belonging to 384 sample households and engaged in cultivation as their primary economic activities constituted the unit of the study.

To classify farmers into the deprived and non-deprived categories a composite multidimensional poverty index (MPI) is constructed at the individual level using Alkire-Foster (AF) approach (Alkire and Foster 2011) with suitable modifications. For the construction of MPI, the study uses six dimensions, seventeen indicators, and an equal nested weighting (ENW) structure (Table 3).

Each farmer is assigned a deprivation score (***Di***), based on deprivation in the component indicator (***ci***) and the weight assigned to the i^{th} indicator (***wi***). For deprivation of farmers in i^{th} indicator, '***ci***' assigned '1' and for non-deprivation assigned '0'. The details about indicator wise deprivation cut-off are given in Table 4.

The composite index for each farmer is estimated by using Eq.(1):

$$Di = \sum_{i=1}^{17} wici = w_1c_1 + w_2c_2 + ... + w_{17}c_{17} \quad ...(1)$$

Individual farmer's deprivation score ($\boldsymbol{D_i}$) lies in

[1]Data retrieved from https://censusindia.gov.in/2011-common/censusdata2011.html

Table 2 Sampling framework

District	Block	No. of Rural Households	No. of Sample Households	Sample Villages	Total No. of Households	No. of Sample Households
Jagatsinghpur	Balikuda	37856	62	Nagapur	526	49
				Khaleri	136	13
	Biridi	19553	32	Alando	329	14
				Batimira	436	18
	Ersama	33703	55	Arada	94	18
				Kothi	200	37
	Jagatsinghpur (P)	32176	53	Baruna	50	16
				Mahakaleswar	115	37
	Kujang	37437	62	Zillanasi	323	25
				Samagol	464	37
	Naugaon	18878	31	Ghodanasa	351	13
				Tentoi	472	18
	Raghunathpur	19918	33	Puja	53	5
				Radhanga	320	28
	Tirtol	34105	56	Ibirisingh	348	21
				Bisunpur	573	35
	Total	233626	384	Total	4790	384

Source Authors' estimates

Table 3 Weight structure in MPI Calculation (ENW and EIW)

Dimension	Weights (ENW)	Weights (EIW)	Indicator	Symbol (ENW)	Weights (EIW)	Weights
Education	0.1667	0.0588	Completed year of schooling	SCHOL	0.1667	0.0588
Health	0.1667	0.1765	Nutritional status (BMI)	NUT	0.0556	0.0588
			Vaccinated / immunized	VAC	0.0556	0.0588
			Insured under the health insurance scheme	HINS	0.0556	0.0588
Standard of Living	0.1667	0.3529	Housing condition	HOUS	0.0278	0.0588
			Access to clean drinking water	WAT	0.0278	0.0588
			Access to electricity	ELCT	0.0278	0.0588
			Ownership of motor vehicle	MV	0.0278	0.0588
			Possession of bank account	BANK	0.0278	0.0588
			Ownership of land	LAND	0.0278	0.0588
Environment	0.1667	0.1176	Practicing open defecation	ODEF	0.0834	0.0588
			Using clean cooking fuel	ENER	0.0834	0.0588
Empowerment	0.1667	0.1765	Autonomy in healthcare decisions	AHTH	0.0556	0.0588
			Autonomy to prevent domestic violence	APDV	0.0556	0.0588
			Autonomy in job choice	AEMP	0.0556	0.0588
Social Connectedness	0.1667	0.1176	Participation in community-level activities	PCOM	0.0834	0.0588
			Organizing community-level activities	OCOM	0.0834	0.0588

ENW: Equal Nested Weight; EIW: Equal Indicator Weight
Source Authors' estimates based on Alkire and Foster (2011) and Trani et al. (2016)

Table 4 Dimensions and indicators of multidimensional poverty (with deprivation cut-off)

Dimension	Indicator	Deprived, if the farmer …
Education	SCHOL	has not completed 6 years of schooling
Health	NUT	is underweight or overweight or obesity measured by BMI
	VAC	not immunized/vaccinated to prevent any type of communicable diseases
	HINS	not insured under any type of health insurance scheme
Standard of Living	HOUS	is living in an inadequate housing condition
	WAT	has no access to safe drinking water
	ELCT	has no access to electricity
	MV	has not owned any type of motor vehicle for transportation purpose
	BANK	has not possessed a savings bank account
	LAND	has not owned any hector of residential land other than where he/she is residing
Environment	ODEF	is practising open defecation
	ENER	is using dirty fuel as primary energy for cooking
Empowerment	AHTH	is unable to take healthcare decision
	APDV	is unable to prevent domestic violence
	AEMP	is unable to take any type of employment decisions for himself/herself other than farming activities
Social Connectedness	PCOM	has not participated in any type of community-level activities
	OCOM	has not been involved in organizing any type of community-level activities

Note Overweight (BMI ≥ 23) and obesity (BMI ≥ 25) act as predisposing factors for non-communicable diseases such as cardiovascular diseases, diabetes, musculoskeletal disorders, and some cancers that kill more people in India in comparison to underweight (BMI < 18.5).
Information retrieved from https://www.nhp.gov.in/disease/non-communicable-disease/obesity
Source Authors' Construction

between '0' and '1', where '0' indicates farmer is non-deprived in all the indicators of multidimensional poverty and '1' indicates farmer is deprived in all the indicators.

In the study, a cut-off level is used to identify the different categories of deprived and non-deprived farmers based on MPI score such as (i) multi-dimensionally non-poor farmer (MNP) with a composite score less than 0.20, (ii) vulnerable to multidimensionally poor farmer (VMP) with a composite score greater than or equal to 0.20 and less than 0.3333, (iii) multidimensionally poor farmer (MP) with a composite score greater than or equal to 0.3333 and less than 0.50, and (iv) severely multidimensionally poor farmer (SMP) with a composite score greater than or equal to 0.50.

The dummy variable multiple regression model (Gujarati and Porter 2009) has been used to examine the impact of education (ED), landholding size (LH), farmer's farming experience (EXP), and social category (SOC) on the MPI. The functional form of the regression model (Eq2) and its econometric specification (Eq3) are specified as:

$$MPI = f(EXP, ED, LH, SOC) \quad \ldots(2)$$

$$MPI = \alpha_1 + \beta_1 EXP + \beta_2 DLPED + \beta_3 DUPED + \beta_4 DSECED + \beta_5 DHSECED + \beta_6 DGRADED + \beta_7 DSLH + \beta_8 DSMLH + \beta_9 DSEBC + \beta_{10} DOBC + \beta_{11} DSC + u_i \quad \ldots(3)$$

In Eq.(3), MPI is the dependent variable, α_1 is constant, β_1 to β_{11} are coefficients of independent variables, and u_i is the error term.

For regression analysis, ED, LH, and SOC are treated as categorical variables, whereas EXP is a continuous variable. Farmer's educational status is grouped into six categories, viz., as no education/illiterate (ILL), lower primary – class 1 to 5 (LP), upper primary – class 6-7 (UP), secondary – class 8 to 10 (SEC), higher secondary – class 11-12 (HSEC), and graduation or above (GRAD). According to landholding size, farmers

Table 5 Famers' profile

Dimension	Indicator	Farmer (in No.)	Farmer (in %)
Gender	Male	206	99.04
	Female	2	0.96
Landholding pattern	Marginal	128	61.54
	Small	52	25.00
	Semi-medium	28	13.46
Social group	SEBC	130	62.50
	OBC	36	17.31
	SC	17	8.17
	General	25	12.02
Education	Illiterate	11	5.29
	Lower primary (LP)	67	32.21
	Upper primary (UP)	41	19.71
	Secondary (SEC)	64	30.77
	Higher secondary (HSEC)	16	7.69
	Graduation and above (GRAD)	9	4.33
Experience (in years)	≤ 10	3	1.44
	11 – 20	30	14.42
	21 – 30	49	23.56
	31 – 40	82	39.42
	41 – 50	35	16.83
	> 50	9	4.33

Source Authors' estimation

are categorized as marginal (below 1.00 hectare), small (1.00-2.00 hectare), semi-medium (2.00-4.00 hectare), medium (4.00-10.00 hectare), and large (10.00 hectare and above) farmers[2]. In Eq.(3) EXP indicates farmer's farming experience, DLPED as lower primary education dummy, DUPED as upper primary education dummy, DSECED as secondary education dummy, DHSECED as higher secondary education dummy, DGRADED as graduation or above education dummy, DSLH as small land holding farm class dummy, DSMLH as semi-medium land holding farm class dummy, DSEBC as socially and economically backward class dummy, DOBC as other backward class dummy, and DSC as scheduled caste dummy.

To check the robustness of the study, equal indicator weight (EIW) structure as proposed by Trani et al. (2016) was used to estimate the MPI (Table 3). In ENW structure all the dimensions are equally weighted, irrespective of the number of indicators that falls under each dimension, whereas in the case of EIW structure, all the indicators are equally weighted and the dimension which consists of a greater number of indicators takes higher weight and the dimension which consists of a smaller number of indicators takes the lower weight.

Results and discussion

The sample households (384) comprise 1953 members, out of which 1616 are in the age group 18 years and above. Out of 1616 members, 673 are not engaged in any economic activities (unemployed – 98, student – 72, housewife – 448 and old age- 55) and the rest, 943 are pursuing some economic activities. Economic activities cover small businesses (107), daily wage earners (143), farmers (208), government jobs (65), private jobs (238), and self-employed (182).

Sample profile (Table 5) of the respondents reveals that all most all farmers are male (99.04%). The percentage of farmers belonging to marginal, small,

[2]Information retrieved from https://pib.gov.in/newsite/PrintRelease.aspx?relid=188051

Table 6 Indicator wise deprivation status of farmers

Indicator	Deprived farmers		Non-deprived farmers	
	In number	In percentage	In number	In percentage
SCHOL	78	37.5	130	62.5
NUT	76	36.5	132	63.5
VAC	0	0.0	208	100.0
HINS	145	69.7	63	30.3
HOU	42	20.2	166	79.8
WAT	0	0.0	208	100.0
ELCT	0	0.0	208	100.0
MV	158	76.0	50	24.0
BANK	55	26.4	153	73.6
LAND	15	7.2	193	92.8
ODEF	155	74.5	53	25.5
ENER	176	84.6	32	15.4
AHTH	7	3.4	201	96.6
APDV	12	5.8	196	94.2
AEMP	3	1.4	205	98.6
PCOM	89	42.8	119	57.2
OCOM	204	98.1	4	1.9

Source Authors' estimation

and semi-medium categories are 61.54, 25.00, and 13.46%, respectively. No farmers with land holdings greater than 4 hectares (medium and large) have been observed. About 95% of the sample farmers are literates, out of which only 12% passed the higher secondary level and above. The study observes about 63% of farmers belong to the SEBC category.

Seventeen indicators have been taken in this study to estimate MPI for each farmer. The deprivation status of farmers across seventeen indicators divulges that none of the farmers is deprived of the three indicators, viz., vaccination, access to clean drinking water, and access to electricity (Table 6). This explains the successful implementation of the government schemes in providing these benefits to farmers in the Jagatsinghpur district. Less than 10% of farmers are deprived of all three indicators measuring empowerment dimension, i.e., autonomy in healthcare decisions, autonomy to prevent domestic violence, autonomy in job choice, and one indicator under the standard of living dimension, i.e., ownership of land. The highest deprivation among farmers is observed in 'organizing community-level activities', falling in the social connectedness dimension. More than 60% of farmers are deprived of four indicators, viz., using clean cooking fuel, ownership of the motor vehicle, practising open defecation, and being insured under the health insurance scheme. Deprivation ranging from 20% to 45% is observed in respect of five indicators, i.e., completed years of schooling, BMI, housing condition, possession of bank account, and participation in community-level activities.

An analysis across dimensions reveals that a higher deprivation level is observed in the case of environment and social connectedness. The environmental dimension comprises using clean cooking fuel and practising open defecation. It is interesting to note that almost all households have availed the benefits of Pradhan Mantri Ujjwala Yojana (PMUY), and Individual Household Latrine (IHHL) under Swachh Bharat Mission (Gramin). But, they are following the usual practice of using wood and cow dung as the major source of cooking fuel and opting for open defecation. Therefore, it is the lack of interest and not lack of opportunity which might be attributed to higher deprivation in the environmental dimension of MPI.

The study estimated MPI using 17 indicators across 6 dimensions adopting ENW structure and the farmers

Table 7 Multidimensional poverty status of farmers across landholding pattern (ENW structure)

Farm class	Total number of farmers	Farmers (in number)				Farmers (in percentage)			
		MNP	VMP	MP	SMP	MNP	VMP	MP	SMP
Marginal	128	0	25	46	57	0.00	19.53	35.94	44.53
Small	52	9	7	15	21	17.31	13.46	28.85	40.38
Semi-medium	28	15	4	9	0	53.57	14.29	32.14	0.00
Total	208	24	36	70	78	11.54	17.31	33.65	37.50
Chi-square ($ð^2$) stat. (p-value.)	72.978* (0.000)								

Source Authors' estimation

Table 8 Impact of demographic and socio-economic variables on MPI

Variables	Coefficient	Std Error	t-stat	p-value
Constant	0.667*	0.043	15.466	0.000
Farming Experience	-0.002*	0.001	-3.027	0.003
Lower Primary Education Dummy	-0.056***	0.029	-1.908	0.058
Upper Primary Education Dummy	-0.267*	0.031	-8.747	0.000
Secondary Education Dummy	-0.304*	0.029	-10.611	0.000
Higher Secondary Education Dummy	-0.363*	0.035	-10.272	0.000
Graduation & above Dummy	-0.391*	0.041	-9.612	0.000
Small Land Holding Dummy	-0.036**	0.015	-2.508	0.013
Semi-Medium Land Holding Dummy	-0.2061*	0.020	-3.046	0.003
SEBC Dummy	0.083*	0.020	4.211	0.000
OBC Dummy	0.045**	0.023	2.015	0.045
SC Dummy	0.080*	0.028	2.834	0.005
R^2 =0.741				
F- statistic (p-value)= 51.04* (0.000)				

NB Dependent variable – MPI (ENW structure);
*, **, *** significance at 1%, 5%, and at 10% level of probability respectively

are classified into four groups, i.e., MNP, VMP, MP, and SMP. The result is given in Table 7.

It is observed that 71.15% of total farmers are either MP or SMP. Only 28.85% are either MNP or VMP. Further, the poverty level decreases with an increase in landholding size. Pearson chi-square value (72.978) is statistically significant at 1% level which establishes the lack of independence between the multidimensional poverty and the landholding size.

Further, the Pearson chi-square values testing the independence of multidimensional poverty and parameters, such as education (224.629), social group (33.012), and experience of the farmers (81.320) are observed to be statistically significant at 1% level indicating the dependence of multidimensional poverty on educational level, social category, and experience of the farmers.

To know the extent of the influence of demographic and socio-economic variables on multidimensional poverty, a dummy variable regression analysis has been undertaken where illiterate, small, and general category farmers have been taken as the reference category. The results are given in Table 8.

A statistically significant F-ratio indicates the validity of the regression model. About 74% variation in MPI is explained by the independent variables taken together. Further, all the four independent variables are statistically significant either at 1, 5 or 10% level.

The regression results indicate that an illiterate, marginal, and general caste farmer belongs to the SMP category (MPI ≥ 0.5) on average. The experience of the farmer is observed to be negatively associated with MPI. With a one-year increase in farming experience, the MPI decreases by 0.002 on average. Similarly, the educational level of the farmers negatively influences the MPI. The MPI decreases at an increasing rate with the rise in the educational level. Higher educational levels and experience improve human capital, and therefore the productivity and income of the farmers. The landholding pattern has also a similar influence on the MPI as that of education. Famers with higher land size are found to be less multidimensionally poor. The positive sign of the regression coefficient in respect of social category indicates that farmers belonging to SEBS, OBC, and SC categories are more susceptible to multidimensional poverty.

The causal relationship between multidimensional poverty and other independent variables such as educational level and landholding pattern is further investigated by projecting the MPI across three landholding groups and six educational levels of farmers.

The projected MPI (Table 9) echoes that farmers with the educational level of lower primary or below belong to SMP irrespective of land possessed by them. When they upgraded themselves educationally to UP level, they are elevated to MP category and a further up-gradation to HSEC and GRAD level finds them in the VMP category irrespective of landholding pattern. Therefore, the study discovers the major role played by education in alleviating multidimensional poverty among farmers.

The results arrived in Table 9 are further extended by incorporating the experience of farmers in the analysis and the results are given in Table 10.

The figures in the cells of the table indicate the experience of farmers (in years) and blank cells indicate no farmers are there in these groups. When MPI is projected considering the experience of the farmers along with their educational level and landholding pattern it is observed that a farmer with a higher

Table 9 Projected multidimensional poverty status of farmers across education and landholding class

Farm class	Illiterate	LP	UP	SEC	HSEC	GRAD
Marginal	0.667	0.611	0.400	0.363	0.304	0.276
Small	0.631	0.575	0.364	0.327	0.268	0.240
Semi-medium	0.606	0.550	0.339	0.302	0.243	0.215
SMP	MP		VMP		NP	

SMP: Severely Multidimensionally Poor; MP: Multidimensionally Poor; VMP: Vulnerable to Multidimensionally Poor; MNP: Multidimensionally Not Poor
Source Authors' projection based on OLS Estimation

Table 10 Projected multidimensional poverty status of farmers across education, landholding class, and experience

	Marginal holdings				Small holdings				Semi-medium holdings			
	MNP	VMP	MP	SMP	MNP	VMP	MP	SMP	MNP	VMP	MP	SMP
ILL				≥ 0				≥ 0			> 52	≤ 52
LP			> 54	≤ 54			> 36	≤ 36			> 24	≤ 24
UP		>32	≤ 32			>14	≤ 14			> 02	≤ 02	
SEC		>14	≤ 14			> 0			>50	≤ 50		
HSEC	>51	≤ 51			>33	≤ 33			>20	≤ 20		
GRAD	>37	≤ 37			>19	≤ 19			>06	≤ 06		

ILL: Illiterate; LP: Lower Primary; UP: Upper primary; SEC: Secondary; HSEC: Higher Secondary; GRAD: Graduation & above; Cell Values indicate years of farming experience
Source Authors' projection

experience level is moving from SMP to MP, from MP to VMP, or from VMP to MNP. Keeping other things equal, viz., educational level, and landholding size, it is projected that a farmer is shifting from a higher to a lower multidimensional poverty group with the rise in experience level. This advocates that a farmer by improving his/her educational level, increasing the landholding size and growing experience can be able to come down in multidimensional poverty ladder.

This research work also measures multidimensional poverty using the EIW structure (Table 3) to assess the robustness of the results. The EIW method measures a smaller number of farmers at each cut-off level of MPI in comparison to the ENW method across marginal and small landholding patterns (Table 11 and Figure 1).

The EIW structure also provides a similar result to that of the ENW structure where the level of multidimensional poverty decreases with an increase in landholding size (Table 12) and educational level (Table 13) of farmers.

Table 11 Comparative analysis of the status of multidimensional poverty measured through ENW and EIW structure across various poverty cut-off levels

Farm class	Weight structure	Poverty Cut-off					
		33.33%	40%	50%	60%	70%	80%
Marginal	ENW	103	71	57	30	2	0
	EIW	81	58	17	2	1	0
Small	ENW	36	31	21	6	1	0
	EIW	33	22	6	0	0	0
Semi-medium	ENW	9	3	0	0	0	0
	EIW	11	1	0	0	0	0
Total	ENW	148	105	78	36	3	0
	EIW	125	81	23	2	1	0

Source Authors' estimation

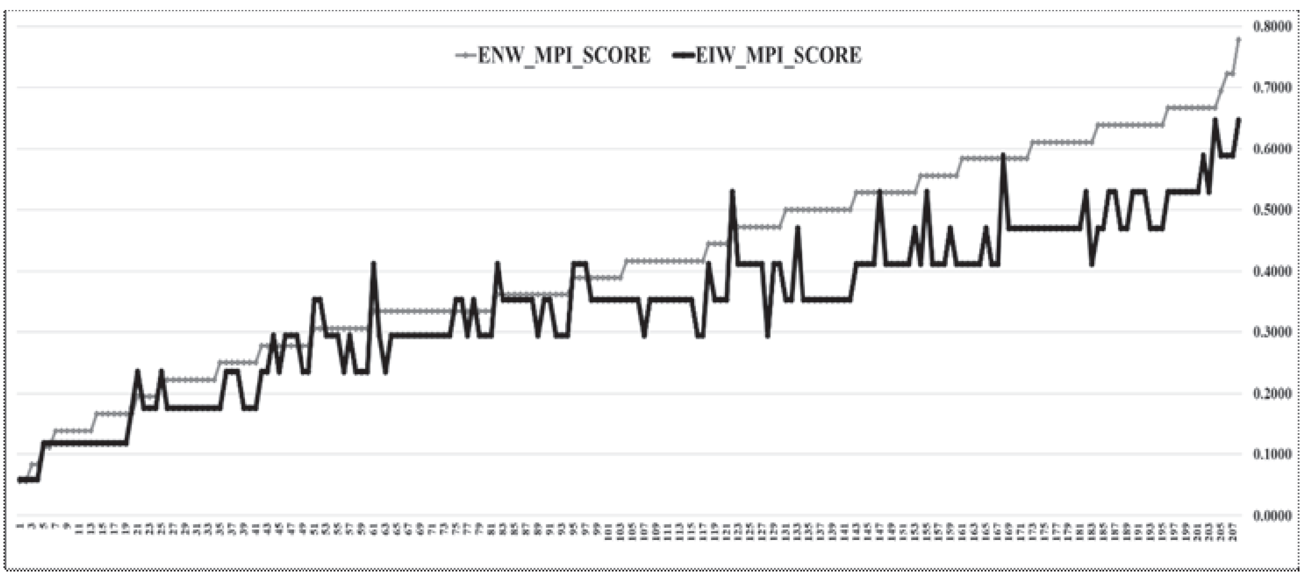

Figure 1 MPI across individual farmers (ENW and EIW structure)
Source Authors' construct

Table 12 Multidimensional poverty status of farmers across landholding pattern (EIW structure)

Farm class	Total number of farmers	Farmers (in number)				Farmers (in percentage)			
		MNP	VMP	MP	SMP	MNP	VMP	MP	SMP
Marginal	128	9	38	64	17	7.03	29.69	50.00	13.28
Small	52	13	6	27	6	25.00	11.54	51.92	11.54
Semi-medium	28	14	3	11	0	50.00	10.71	39.29	0.00
Total	208	36	47	102	23	17.31	22.60	49.04	11.06

Source Authors' estimation

Table 13 Multidimensional poverty status of farmers across different educational levels (EIW structure)

Education level	Total number of farmers	Farmers (in number)				Farmers (in percentage)			
		MNP	VMP	MP	SMP	MNP	VMP	MP	SMP
ILL	11	0	0	6	5	0.00	0.00	2.88	2.40
LP	67	0	4	50	13	0.00	1.92	24.04	6.25
UP	41	5	14	21	1	2.40	6.73	10.10	0.48
SEC	64	18	21	22	3	8.65	10.10	10.58	1.44
HSEC	16	9	3	3	1	4.33	1.44	1.44	0.48
GRAD	9	4	5	0	0	1.92	2.40	0.00	0.00
Total	208	36	47	102	23	17.31	22.60	49.04	11.06

Source Authors' estimation

Conclusions

This study assesses the magnitude and determinants of multidimensional poverty among farmers in the Jagatsinghpur district of Odisha. The findings showed that about two-thirds of the farmers are either multidimensional poor or severe multidimensional poor. More than 50% of farmers are deprived of five indicators, i.e., using clean cooking fuel, having ownership of the motor vehicles, practising open defecation, coverage under the health insurance scheme, and organizing community-level activities. The highest concentration of poverty is observed among illiterate and marginal farmers with a lower level of experience. The MPI decreases with an increase in the educational level and experience of the farmers. The study also observed a decrease in the MPI with an increase in landholding size and a lower MPI for a general category farmer in comparison to SC, SEBC, and OBC categories.

The observations of the study have significant practical relevance for policymakers. Since the majority of farmers use dirty cooking fuel and go for open defecation despite their access to these services, the study suggests the reorientation of policy measures in creating more awareness among them to use clean cooking fuel and household latrines along with stringent actions against the violators. Adequate coverage of marginal and small farmers may be ensured under Biju Krushak Kalyan Yojana (BKKY) and Biju Swasthya Kalyan Yojana (BSKY), implemented by the Government of Odisha, to bring more farmers under the grasp of health insurance.

The study echoes the important role played by education in ameliorating the multidimensional poverty of the farmers in the study district. Despite the operation of various schemes, such as the Right to Education Act, Early Childhood Care and Education (ECCE) Programme, and Learning Enhancement Programmes (LEP), namely Ujjwal, Utthan, and Utkarsh, implemented by the Government of Odisha in reducing the dropout rates, the dropouts in primary and secondary level is increasing over the years. This calls for reorientation and strict implementation of these policies in the study district.

The experience of the farmers enhances the skill of the farmers in cultivation. Consequently, this helps in the enhancement of the productivity and income of the farmers. Although the government of Odisha is implementing various schemes like Krushak Assistance for Livelihood and Income Augmentation (KALIA), Ama Krushi, Mukhyamantri Abhinav Krushi Jantrapati Samman (MAKJS), and Agricultural Entrepreneurship Promotion Scheme 2018, etc. to provide support to farmers in accelerating agricultural prosperity and reducing poverty among farmers, these policies are not precisely designed for skill development of farmers. Therefore, the study suggests that the policy may be reoriented towards skill development of the farmers, more specifically marginal and small farmers to increase their productivity and lessen the multidimensional poverty among them.

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Correlates of multidimensional poverty in rural Bihar

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Abstract Reducing poverty has been the cornerstone of several development policies. Yet, reducing it on income level has not yielded much result, as income-based poverty fails to capture other dimensions of deprivations. This study, using data from the 7th DHS survey, constructs a Multidimensional Poverty Index (MPI) for 38 districts of rural Bihar and its correlates. The extent of multidimensional poverty is very high, varying from 0.19 in Rohtas to 0.39 in Araria. Further analysis shows that MPI is affected by the access to clean cooking fuel, improved sanitation facilities and education.

Keywords Multidimensional poverty, regression tree analysis, Bihar, India

JEL Codes C43, C38, I32, I38

Reducing poverty has been the cornerstone of India's development plans since independence. Despite this, poverty and its effects remain a persistent problem. The link between poverty reduction and realized welfare has also been debated. Although income, poverty and welfare seem to be related, the literature (Alkire 2005, Laderchi 1997, Sharma 1995) advocates that income alone should not be considered as the sole indicator for estimating poverty because of its non-linear relationship with other indicators of welfare. Therefore, a need arises to examine poverty through a multidimensional lens. Evidence suggests that the extent of poverty in India is highest in rural Bihar (Alkire 2015, Alkire et al. 2014, Panagariya and Mukim 2014). Chapoto et al. (2011) enumerated agricultural (including livestock) asset accumulation and commercialization, investment in secondary and post-secondary education, health shocks, lower access to markets as key factors in influencing poverty in developing countries. He suggested investment in these areas could help people escape poverty. Dhamija (2011) using panel data found that village-level infrastructure, rural-urban linkages, size of the village, and ownership of land and livestock play a significant role in reducing poverty in India. Krishna (1993) identified ill-health, high health care costs, high interest on private debts, droughts, and social and customary expenses as major contributing factors to poverty. Diversification of income sources, investment in health care facilities, education, industrial growth, land improvement were suggested for reducing poverty. Sharma (1995) estimated poverty using National Sample Survey (NSS) expenditure data and found that land, poor employment opportunities, the primitive form of agriculture and industries, faulty delivery systems, poor infrastructures and low assets and literacy were major causes of higher poverty in Bihar. Land reforms, rural industrialization, investment in irrigation, flood control, rural power supply, and education were suggested for reducing the poverty. He also supported inclusion of other indicators for measuring poverty. According to Singh et al. (2011), deprivation in education, caste, ownership of productive assets (like land and livestock), and lack in access to communication and information technology and institutional credit as major factors underlying the poverty in Bihar. This study aims to analyze the indicators that influence the present poverty status.

Our study contributes to the existing literature in several ways. First, it uses a large representative dataset. Second, it also uses deprivation in indicators other than income for analyzing poverty. Since 76% of the population of Bihar is involved in agriculture, it includes several indicators related to agriculture and livestock.

Methodology

Data

Multidimensional Poverty Index (MPI) was calculated using data from the 7th Demographic and Health Survey (DHS) 2015-16. We followed Alkire and Foster (2011) to estimate multidimensional poverty. MPI mainly gives information about the extent of poverty as well as the average number of dimensions in which the poor are deprived. It can be estimated as:

$$M_0 = H \times A$$

Where, H is the poverty headcount ratio, $H = \frac{q}{n}$, and A represents the intensity of poverty i.e., the average number of deprivations faced by the poor, $A = \frac{\sum_{i=1}^{n} C_i(k)}{q}$.

The construction of H and A involves the selection of a set of indicators under each dimension. Then using the dual cut-off approach, the poor in each district are identified and aggregated. The indicators and dimensions and their respective cut-off considered in analyzing MPI are given in Table 1. The indicators used are the necessary factors for increasing the productive capacity of individuals, which in turn increases the efficiency of human capital and thereby promote economic growth. Thus, analyzing the domains responsible for multidimensional poverty can help in reducing poverty and increasing the welfare of the masses. Since a majority of the independent variables are categorical, a regression tree analysis was performed for analyzing the factors influencing the level of poverty. Regression tree analysis is a data mining technique that uses a variance minimizing approach to identify variables among a vector of factors. It is a non-parametric approach that explains the effects of independent continuous or categorical variables on the dependent variable. The tree is built on the algorithm of recursively splitting the data into different child nodes to attain homogeneity based on the given partition criteria or the dependent variable (Ramadas et al. 2021). Therefore, the root node (data set) is divided into other nodes (sub-samples) and this process continues till the decisive criteria are met. Finally, the process ends at the terminal node. The fundamental functional form used is: $Y_i = f(x_1, x_2 \ldots x_n)$

Where, Y is the dependent variable i.e., MPI for 38 districts in Bihar, and the explanatory variables include years of schooling, child school enrollment, nutritional status, child mortality, access to drinking water, sanitation, cooking fuel, electricity, housing conditions and life-sustaining assets.

Results and discussion

Table 2 presents the summary of the population deprived in different indicators in rural Bihar. A majority of the population is deprived of clean cooking fuel facilities, followed by asset ownership, improved sanitation facilities, better housing conditions, nutrition, access to electricity, education, and child attendance in school. The variation is the highest in the case of access to electricity and the lowest in the child mortality rate. Sharma (1995) reported that 50 to 70% of the wage earners in Bihar were deprived of nutritious food (both qualitatively and quantitatively), pucca houses, and agricultural assets. Only 15% of them owned a bicycle and a majority of the children were deprived of school education. Hence, to get a complete picture of the extent of poverty, a multidimensional poverty index was constructed for each of the districts and then the districts were categorized as low, moderate and high based on the magnitude of multidimensional poverty index (Sinha et al. 2021).

Figure 1 shows the intra-state variation in multidimensional poverty. The extent of poverty varies from 0.19 in Rohtas to 0.39 in Araria. A majority of the districts in the high multidimensional poverty zones are in north Bihar, which is highly vulnerable to climatic events (floods). The districts in moderate and low MPI zones lie in the central and southern parts of the state. This indicates that a higher extent of deprivation and climatic events make people fall back into poverty traps. To decipher the factors that are likely to increase the extent of multidimensional poverty, a regression tree analysis has been carried out. The results are presented in Figures 2 and 3.

Table 1 Dimensions and indicators included for constructing the MPI

Dimensions	Indicators (explanatory variables)	Deprivation cut-off	Weights
Education	Years of schooling	If household members aged 10 years orolder has completed 6 years of schooling	1/6
	Child school enrollment	Any school-aged child is not attending school up to class 8	1/6
Health	Nutrition	Individual or child in the household is malnourished*	1/6
	Child mortality	Any child died in the household in the last five years preceding the survey.	1/6
Standard of living	Drinking water	The household has no access to safe drinking water (according to SDG guidelines)** or if it takes more than 30 minutes to reach the clean water sources.	1/18
	Sanitation	Household's sanitation facility was not improved (according to SDG guidelines)***, or if improved but shared with other households.	1/18
	Housing conditions	Materials used for constructing the roof, walls and floor are inadequate****	1/18
	Cooking fuel	Lack of improved cooking fuel.#	1/18
	Electricity	Lack of electricity.	1/18
	Assets	The household doesn't have access to more than 2 assets, agricultural assets or tractor)	1/18
	Access to information and communication (Radio, Television, Telephone/ mobile-telephone)		
	Supporting the mobility (Bike, bicycle, animal cart, tractor)		
	Support livelihood (own agricultural land, livestock and other agricultural equipment)		

*The adult (20 to 70 years old) is considered malnourished if the BMI is less than 18.5 kg/m^2. Those between 5 to 20 years of age are malnourished if the age-specific BMI is below minus two standard deviations. Children under 5 years are categorized as malnourished if their z-score for either height-for-age (stunting) or weight-for-age (underweight) is below minus two standard deviations from the median of the reference population.

**Clean drinking water sources: Piped water, public tap, borehole or pump, protected well, protected spring or rainwater, and it is within 30 minutes walk (round trip).

***Adequate sanitation facilities: some type of flush toilet or latrine, or ventilated improved pit or composting toilet and are not shared with other households.

****Inadequate flooring: If the floor is made of mud/clay/earth, sand or dung or if a dwelling has no roof or walls or if either the roof or walls are made of natural materials such as cane, palm/trunks, sod/mud, dirt, grass/reeds, thatch, bamboo, sticks or rudimentary materials such as carton, plastic/ polythene sheeting, bamboo with mud/stone with mud, loosely packed stones, uncovered adobe, raw/reused wood, plywood, cardboard, un-burnt brick or canvas/tent.

Liquefied Petroleum Gas (LPG) is taken as improved cooking fuel, other than LPG has been kept as unimproved cooking fuel category.

Table 2 Indicator wise summary statistics in rural Bihar (% of the deprived population)

Parameter	Years of education	Child attendance	Child mortality	Nutrition	Electricity	Sanitation facilities	Drinking water facilities	Housing conditions	Cooking fuel	Assets ownership
Maximum value	43.64	20.89	8.21	58.72	57.1	70.18	17.18	59.1	73.04	71.2
Minimum value	10.01	3.68	2.56	34.92	13.15	40.86	0	9.15	43.62	44.03
Range	33.63	17.21	5.65	23.8	43.95	29.32	17.18	49.95	29.42	27.17
Mean	27.08	12.21	4.65	46.36	31.26	54.16	1.68	29.24	57.66	57.39

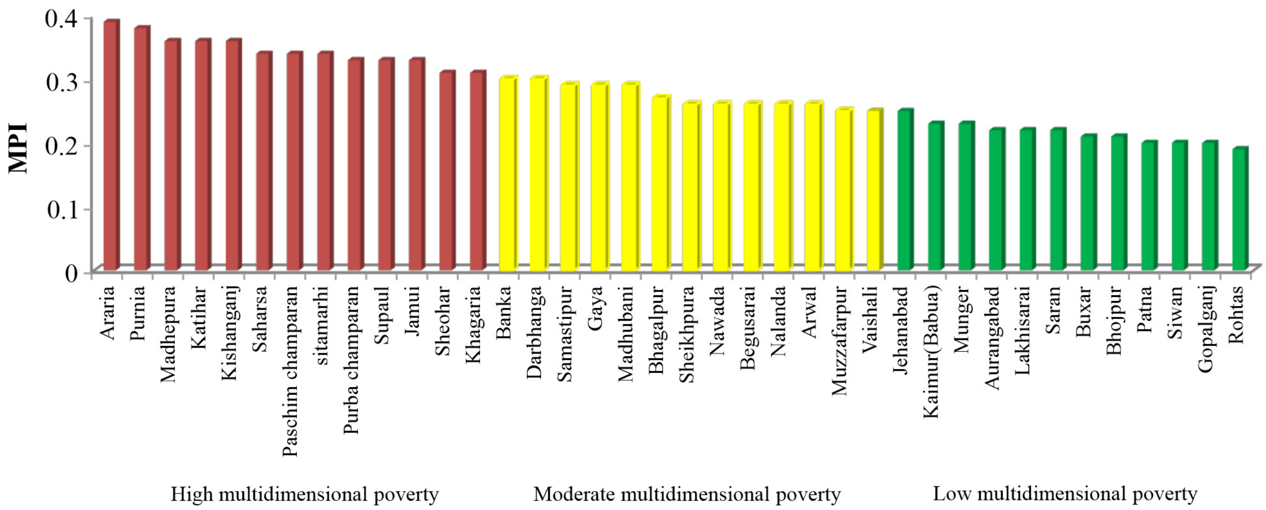


Figure 1 Extent of multidimensional poverty in districts of Bihar

Regression tree analysis helps to know the correlates of multidimensional poverty in each of the 38 districts, that are categorised into high, medium and low (Sinha et al. 2021). A perusal of the regression tree (Figure 2) indicates that the low and moderate MPI districts are grouped against the high MPI districts. The high multidimensional poverty zone gets further sub-divided depending on years of schooling. The districts with more than 39% of the households with members receiving schooling of fewer than 6 years cause an increase in MPI by 0.370. The low and moderate zones of MPI are further divided based on access to clean cooking fuel. The districts in which more than 52% of the households are deprived of clean cooking fuel have a higher MPI (0.271). The districts in which the deprivation to clean cooking fuel was more than 52%, are further subdivided based on access to improved sanitation facilities. Nodes 7 and 8 shows that a higher deprivation in improved sanitation facilities increases the extent of multidimensional poverty.

To reduce the extent of deprivation in education, both supply and demand-side factors need to be improved. On the supply side, access to schools can be increased by providing incentives to students (Muralidharan and Prakash 2017, Das and Sarkhel 2019), teacher performance (Karthik and Venkatesh 2011), and collective incentive of the locals (Banerjee et al. 2017). Lack of proper infrastructure, low pupil-teacher ratio, low household income, poor functioning of Mid- day Meal scheme are the major lacunae that need to be addressed for improving access to education (Ghosh and Rana 2011, Ranjan and Prakash 2012). The demand for education can be improved by increasing the employment status. Lack of access to clean cooking fuel and improved sanitation can lead to several water-borne and respiratory diseases (Lai et al. 2012) and ultimately lowers the income of people. Increasing access to improved sanitation requires changing the attitude of the people, modifying it according to social norms and making it affordable (Sinha et al. 2017,

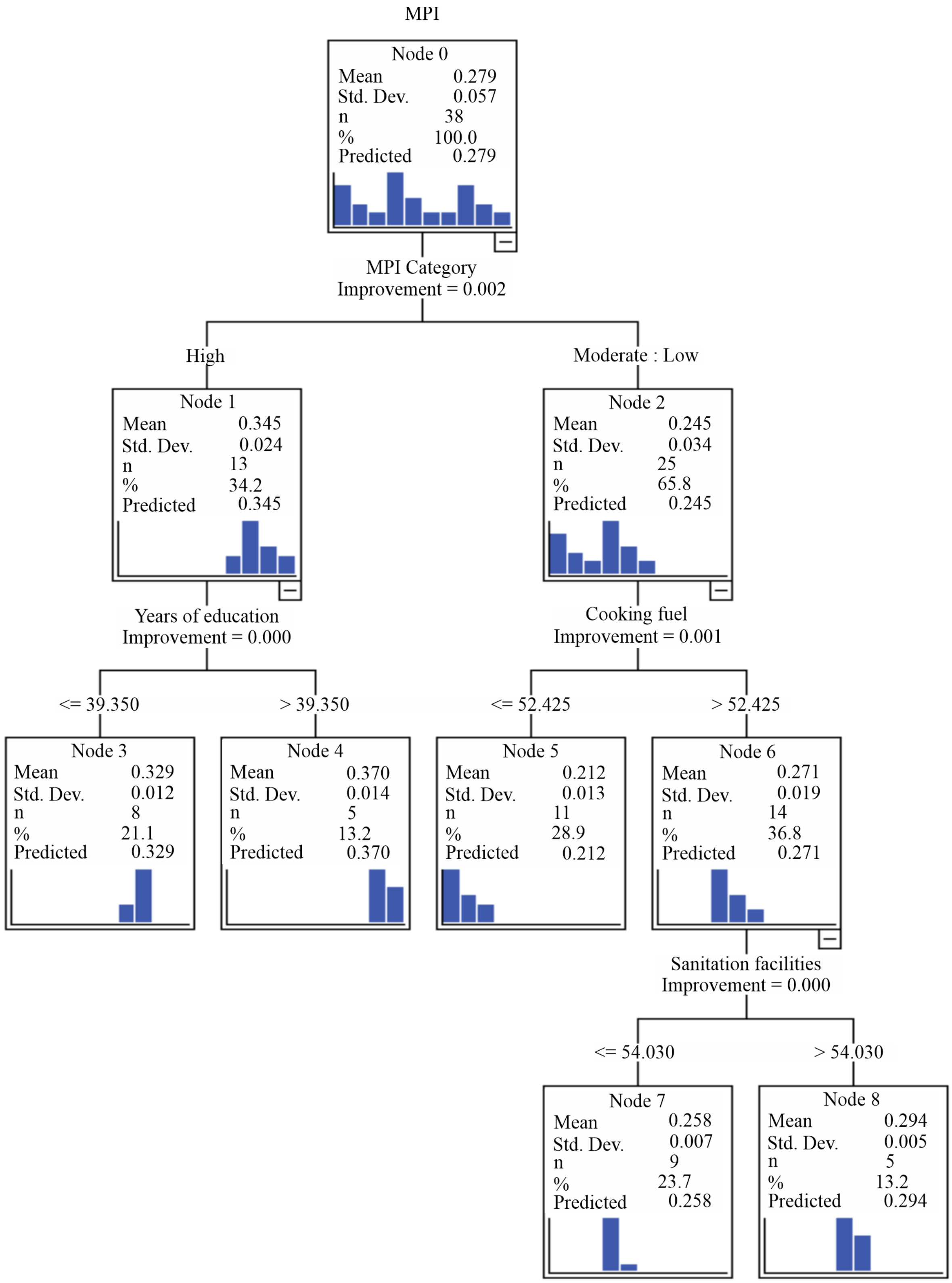
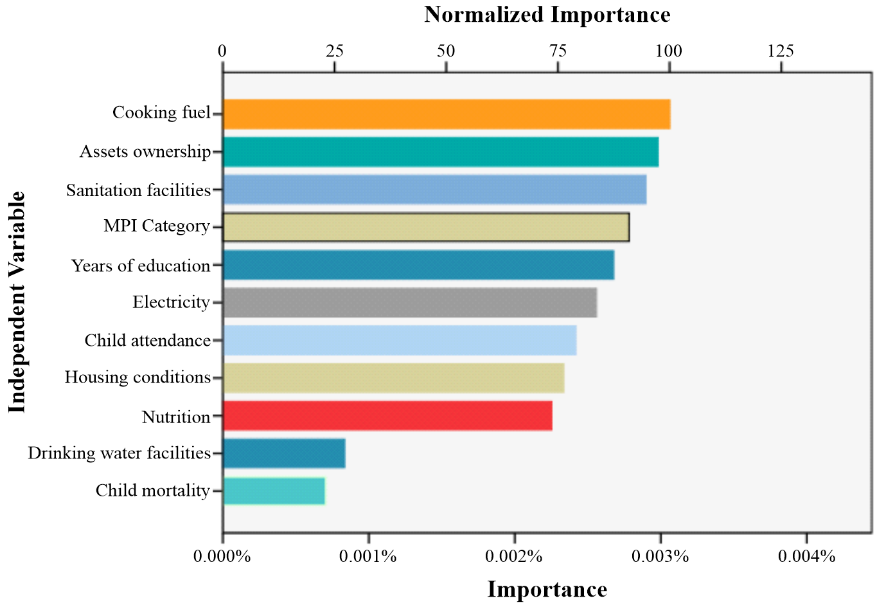


Figure 2 Determinants of multidimensional poverty in different poverty zones



Growing Method: CRT

Figure 3 Explanatory variables influencing MPI

Novotný et al. 2018). Easy accessibility of other fuels makes it difficult to switch to using clean cooking fuels (Gould and Urpelainen 2018). Therefore, increasing the availability and affordability can help increase the adoption of clean cooking fuels.

Conclusions

This study analyzes the correlates of the multidimensional poverty in rural Bihar. The analysis revealed that enhanced investment in the provision of improved sanitation facilities, providing subsidies for the construction of improved toilets and refills in cooking fuel will help in reducing the extent of multidimensional poverty in low and moderate zones. Investment in education infrastructure, increasing the teacher-pupil ratio, providing a combination of information-incentive to parents, children and teachers can help in improving the educational attainment and thereby will reduce the extent of multidimensional poverty in high incidence regions. To conclude, a different combination of measures should be applied depending on the extent of deprivation across regions in addressing the issues of multidimensional poverty.

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Inter-state variation in technical efficiency and total factor productivity of India's livestock sector

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Abstract During last two and half decades (1990-2016), the Total Factor Productivity (TFP) of livestock sector has grown at an annual rate of 3.9%. However, there are significant variations in it across states. It is estimated very high in Tamil Nadu (8.7%), Andhra Pradesh (7.6%) & Odisha (7.6%) and extremely low in Jammu & Kashmir (0.6%), Himachal Pradesh (-0.4%) and Bihar (-4.3%). Interestingly, TFP growth has been driven by technical change. The estimates of scale efficiency indicate scope of raising output by about 30% even at the existing levels of input-use. The findings suggest the need for greater investment in animal science research and development, especially in the states that have poorly performed on technological front.

Keywords Livestock, TFP, technical efficiency, scale efficiency, returns to scale

JEL Codes O3, Q1,

Economic liberalization and globalization have opened up significant opportunities for market-led growth of livestock sector. The demand for livestock products has been witnessing a continuous surge (Gandhi and Zhou 2010). By 2030, global demand for milk and meat is expected to rise by 33% and 19%, respectively above their levels in 2015-17 (FAO 2018). This presents an opportunity for alleviation of poverty and improving nutritional security. The development of livestock sector will have direct or indirect impacts on nearly 16.44 million rural households in India GoI (2020). In the past five years, India's livestock sector grew at an annual rate of 8% GoI (2019). Nevertheless, livestock production remains constrained by several factors such as the small herd size, scarcity of feeds and fodder and poor delivery of breeding and veterinary services.

India's livestock is characterised by low levels of productivity and input use. Hence, there is a need to look for the ways to enhance productivity of inputs either by the generation of new technologies or improving efficiency of input use. Crossbreeding with exotic breeds has been a prominent technology in India since the 1960s. Previous studies have documented the evidence of productivity-led growth in the crop sector (Kumar and Mruthyunjaya 1992; Kumar and Rosegrant 1994; Evenson et al.1999; Murgai 1999; Joshi et al. 2003; Kumar et al. 2004; Coelli and Rao 2005; Chand et al. 2011; Chaudhary 2012). However, similar studies for the livestock sector are scarce (Birthal et al.1999; Avila and Evenson 2010).

This study is an attempt to understand whether India's livestock sector has experienced technological progress or not. Estimation of TFP growth and its decomposition has been carried out to identify the sources of productivity growth. Along with the TFP, the measures of technical efficiency and scale efficiency for each state have also been estimated.

Methodology

TFP is a measure of the contribution of improved technologies which could be on account of research, extension, education, infrastructure and policy interventions. These factors also enhance productivity of inputs. This study uses non-parametric Malmquist index (DEA approach) to measure TFP. DEA can be either input-orientated or output-orientated. We applied the latter, since it provides a maximum proportional increase in output level with input levels held constant (Coelli and Rao 2005). The estimated technical efficiency scores remain the same, irrespective of whether we apply input-oriented or output-oriented DEA under constant returns to scale (CRS), but these vary under variable returns to scale (VRS).

Technical efficiency under CRS and VRS can be estimated by solving a linear programming problem (Ali and Seiford 1993):

$$\max_{\theta,\lambda} \theta_i$$

Subject to

$$\sum_{j=1}^{n} \lambda_j x_{kj} + e_k = x_{ki}$$

$$\lambda_j \geq 1; s \geq 0; e_k \geq 0$$

Where θ_i is the proportional increase in output for the i^{th} state, λ_j is an N × 1 vector of weights relative to efficient observations, s is the output slack, and e_k is the k^{th} input slack. By adding the convexity constraint N1'λ = 1, the CRS model can be modified into VRS DEA (Banker et al. 1984). When the values of θ and λ_i are equal to 1, and λ_j= 0, the Decision Making Unit (DMU) is said to be efficient. By contrast, when $\theta > 1$, λ_i= 0, and $\lambda_j \neq 0$, it is inefficient.

Scale efficiency (SE) is obtained by comparing the difference between TE(CRS) and TE(VRS). If the difference lies between the two scores, that means there is scale inefficiency. SE varies from 0 to 1, where a value of 1 indicates full-scale efficiency and less than 1 indicates the presence of scale inefficiency.

SE can be calculated as follows (Coelli, 1996):

$$SE_i = \frac{TE_i^{CRS}}{TE_i^{VRS}}$$

Malmquist TFP index method

The Malmquist Productivity Index (MPI) is a measure of productivity change that relies on the distance functions. It allows estimation of multi-input and multi-output production functions without any explicit price data or any assumption regarding economic behaviour such as profit maximization or cost minimisation. The advantage of this method is its ability to decompose TFP growth into four components: (a) changes in technical efficiency over time (catching-up), (b) shifts in technology over time (technical change), (c) pure efficiency changes, (d) scale efficiency changes. Pure technical efficiency shows how the resources are managed in a production unit while scale efficiency reflects whether the production unit operates at an optimal scale or not.

The productivity change index (MPI) using technology at period *t* as reference is defined as:

$$M_0^t(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)}\right]$$

If we take *t+1* period technology as a reference, MPI would be:

$$M_0^{t+1}(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)}\right]$$

Fare et al. (1994) specify an output-oriented geometric mean of two indices given above to avoid choosing an arbitrary period of reference.

$$M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{d_0^t(x_{t+1}, y_{t+1}) d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t) d_0^{t+1}(x_t, y_t)}\right]^{\frac{1}{2}}$$

MPI can further be decomposed into two components: Efficiency change and Technical change:

$$EFFCH = \left[\frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)}\right]$$

$$TECHCH = \left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_{t+1}, y_{t+1})} \times \frac{d_0^t(x_t, y_t)}{d_0^{t+1}(x_t, y_t)}\right]^{\frac{1}{2}}$$

Efficiency change (EFFCH) is the efficiency change index that measures the output-oriented shift in technology between two periods. If it is greater than 1, then there is an improvement in productive efficiency, otherwise there is the degradation of the given unit. Similarly, TECHCH measures technical change between two periods. If it is greater than 1 then it means technological progress.

Data and variables

The study relies on secondary data from various published and unpublished sources. Data are collected for 16 major states for 1990-91 to 2015-16.

Value of output: Data on total value of output from the livestock sector was collected from National Accounts Statistics. The data was converted into constant (2015-16) prices using the GDP deflator.

Inputs: Three major input groups used are: feed, labour and animal stock. State-wise green fodder production was estimated using the area under green fodder. An average yield of 50 t/ha (*CSO*, 2018) was assumed. Similarly, the land under permanent pastures, cultivable wasteland, grazing land, land under miscellaneous uses were clubbed to estimate fodder availability. State-wise data on the annual value of straw and stalks was taken from the *Central Statistics Office* (CSO) and converted into constant 2015-16 prices.

To estimate the labour use in livestock production, the data on agricultural labourers and cultivators were collected from Population Census 1991, 2001 and 2011. It was assumed that one-fourth of male and three-fourth of female cultivators/agricultural labourers are engaged in livestock activities. Further, it was assumed that three women labourers are equivalent to two men labourers (Elumalai and Pandey 2005; Chand and Sirohi 2015). Interpolation was done to estimate the labour for inter-census periods.

Animal stock is the total number of cattle, buffalos, sheep, goats, pigs and poultry measured in Standard Animal Units (SAU) Sirohi et al. (2019). The data on livestock population was compiled from various rounds of livestock census from 1992 to 2019. Data for inter-census period were linearly interpolated.

Results and discussion

Technical and scale efficiency

The technical efficiency measures have been estimated for each state, both under constant returns to scale (CRS) and variable returns to scale (VRS) and summarized in Table 2. Results indicate an average technical efficiency score of 0.654 under CRS and 0.927 under VRS. Haryana, Punjab, Jammu &Kashmir (J&K), Kerala, West Bengal and Bihar are operating under full technical efficiency (CRS), while Himachal Pradesh, Uttar Pradesh and Odisha have shown full technical efficiency only under VRS. In other states, livestock output produced is much lower than the maximum level that can be achieved by using the available inputs under given technology. This implies that these states have enormous scope to improve their efficiency using the technical inputs at their disposal.

The average scale efficiency is 0.689%, which implies that the possibility of increasing output by about 30% still exists. Further analysis shows that Haryana, Punjab, J&K, Bihar, West Bengal and Kerala have an optimal level of scale efficiency under CRS. Scale-inefficient states are Uttar Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Rajasthan, Gujarat, and Madhya Pradesh. The average herd size in these states is supra-optimal, which could be reduced to reach an optimal scale. Himachal Pradesh and Odisha are the only states, operating under increasing returns to scale, exhibiting sub-optimal performance; the average herd size in these states could be increased to achieve full-scale efficiency.

Table 1 Summary statistics

Region	Mean					
	Value of output (Million Rs)	Dry fodder (Million Rs)	Green fodder (‘000 tons)	Labour (‘000 man-equivalents)	Pasture (‘000 ha)	Animal stock (SAU in ‘000)
East	20761	3445	317	5357	584	20700
North	23948	3173	21300	3734	773	14900
South	22626	1683	4600	5017	996	14400
West	29271	5283	73900	8809	3750	26000
Overall	24351	3379	26400	5628	1538	18600

Table 2 Technical and scale efficiency

State	Technical efficiency (CRS)	Technical efficiency (VRS)	Scale efficiency	Returns to scale
Haryana	1.000	1.000	1.000	Constant
Punjab	1.000	1.000	1.000	Constant
Jammu &Kashmir	1.000	1.000	1.000	Constant
Bihar	1.000	1.000	1.000	Constant
West Bengal	1.000	1.000	1.000	Constant
Kerala	1.000	1.000	1.000	Constant
Himachal Pradesh	0.588	1.000	0.588	Increasing
Odisha	0.365	1.000	0.365	Increasing
Uttar Pradesh	0.483	1.000	0.483	Decreasing
Andhra Pradesh	0.523	0.982	0.533	Decreasing
Karnataka	0.505	0.859	0.588	Decreasing
Tamil Nadu	0.59	0.842	0.701	Decreasing
Maharashtra	0.396	0.865	0.457	Decreasing
Gujarat	0.513	0.827	0.62	Decreasing
Rajasthan	0.242	0.736	0.329	Decreasing
Madhya Pradesh	0.262	0.719	0.365	Decreasing
Mean	0.654	0.927	0.689	

Total factor productivity growth

This section describes growth in TFP indices under the assumption of CRS. Rather than limiting the discussion to the direction of change in the TFP index, we have attempted to study the change in magnitude of the index in terms of growth rate as well. TFP index value of less than 1 indicates declining productivity or vice versa. For the detailed annual mean TFP indices refer to appendix Table A1. For simplifying the interpretation, average TFP growth rates have been presented in Table 3. Besides the average TFP growth rate for the period 1990 to 2016, growth rate at three sub-periods, i.e., triennium ending (TE) 1992-93, 2002-03 and 2015-16 have also been presented for a better understanding. The estimates suggest positive TFP growth in the livestock sector. Except for J&K and Bihar, all other states have witnessed a positive change in TFP growth. Although in terms of overall productivity the performance of Tamil Nadu, Andhra Pradesh and Odisha has been better (Table 3), the sub-period growth rates reflect a more realistic pattern.

In the northern region, the TFP growth has been highest for Haryana (5.6%), followed by Punjab (4.8%) and UP (3.9%). Hill states such as HP and J&K are poor performers on technological progress. TFP growth for the southern states has been positive. Tamil Nadu registered the highest growth of 8.7%, followed by AP (7.6%) while Kerala (4.9%) and Karnataka (4%) have also fared well. In the eastern region, Bihar with an average TFP growth of -0.4% is the poorest performer on technological progress. Despite being one of the agriculturally backward states, Odisha has overall high livestock productivity growth (7.6%) in the eastern region which can be attributed to the successful adoption of crossbreeding technology (Sirohi 2005). In the western region, Rajasthan has the highest TFP growth of 5.9%, followed by Maharashtra (5.5%) and Gujarat (3.4%).

An analysis by sub-period shows that in the northern region, Haryana witnessed a huge decline in its productivity growth, from an average of 6.6% to a negative of 0.3% in TE 2002-03, which recovered to reach 8.5% in TE 2015-16. Punjab has been faring well throughout, suggesting that the state has been on the path of technical progress. Uttar Pradesh, on the other hand, performed poorly initially, but has shown significant improvement later on. Jammu &Kashmir too has been able to accelerate its growth from –18.7% to 12.3% in TE 2015-16. Himachal Pradesh has

Table 3 TFP growth rate in India's livestock sector

States	TFP change (%)			
	TE 1992-93	TE 2002-03	TE 2015-16	1990-2016
Tamil Nadu	10.3	4.1	13.9	8.7
Andhra Pradesh	11.0	19.4	30.3	7.6
Odisha	12.8	5.0	2.5	7.6
Rajasthan	7.0	-12.9	17.5	5.9
Haryana	6.6	-0.3	8.2	5.6
Maharashtra	3.5	0.1	17.9	5.5
Punjab	16.0	16.1	25.0	4.8
Kerala	15.0	-2.0	0.8	4.9
Karnataka	3.5	-1.2	11.7	4.0
Uttar Pradesh	-0.9	-1.2	13.2	3.9
West Bengal	3.5	2.0	9.5	3.9
Gujarat	4.2	-1.6	5.8	3.4
Madhya Pradesh	3.5	-9.4	15.2	1.6
Himachal Pradesh	-1.9	4.4	4.6	0.6
Bihar	-17.8	3.9	9.0	-0.4
Jammu &Kashmir	-18.7	-14.9	12.3	-4.3
Mean	3.6	0.7	12.3	3.9

experienced nearly constant growth of about 4% since 2000 (Table 3).

In the southern region, Tamil Nadu is the top performer, followed by Andhra Pradesh. Kerala which was one of the best performing states in TE 1992-93 experienced a decline in productivity growth in the latter periods. Tamil Nadu and Karnataka have shown continuous improvement in productivity growth, except in TE 2002-03. In the western region, TFP growth deteriorated in the TE 2002-03. Maharashtra experienced considerable good growth after TE 2002-03. A similar trend is observed for Rajasthan, Gujarat and Madhya Pradesh.

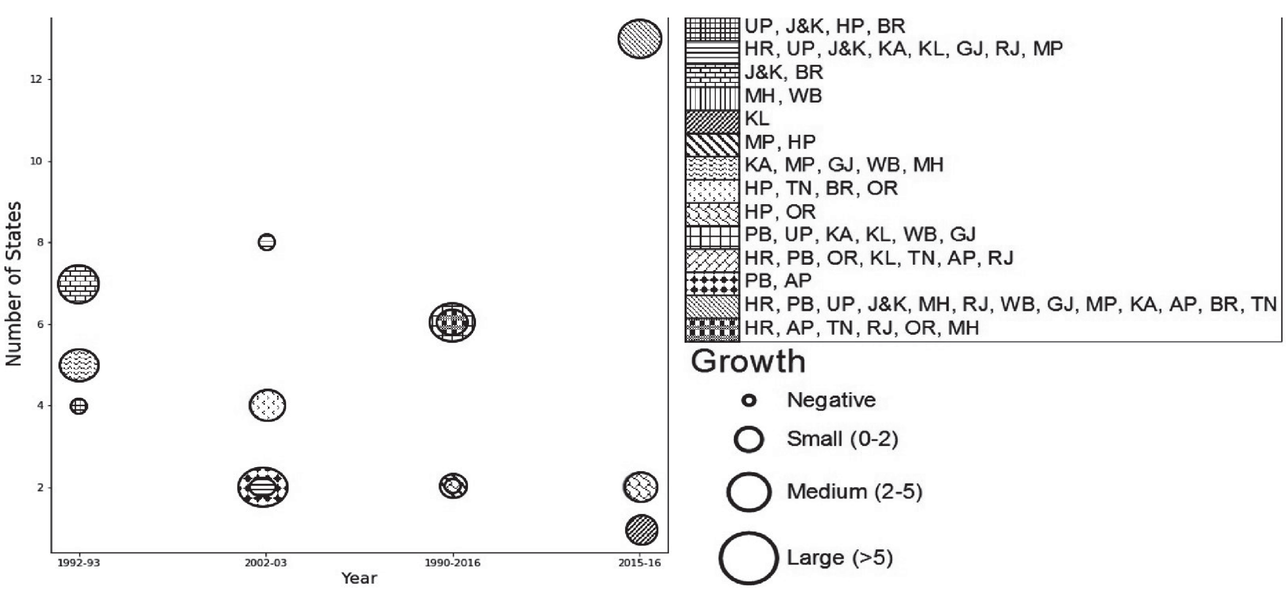

Figure 1 Trends in TFP growth rates in India's livestock sector

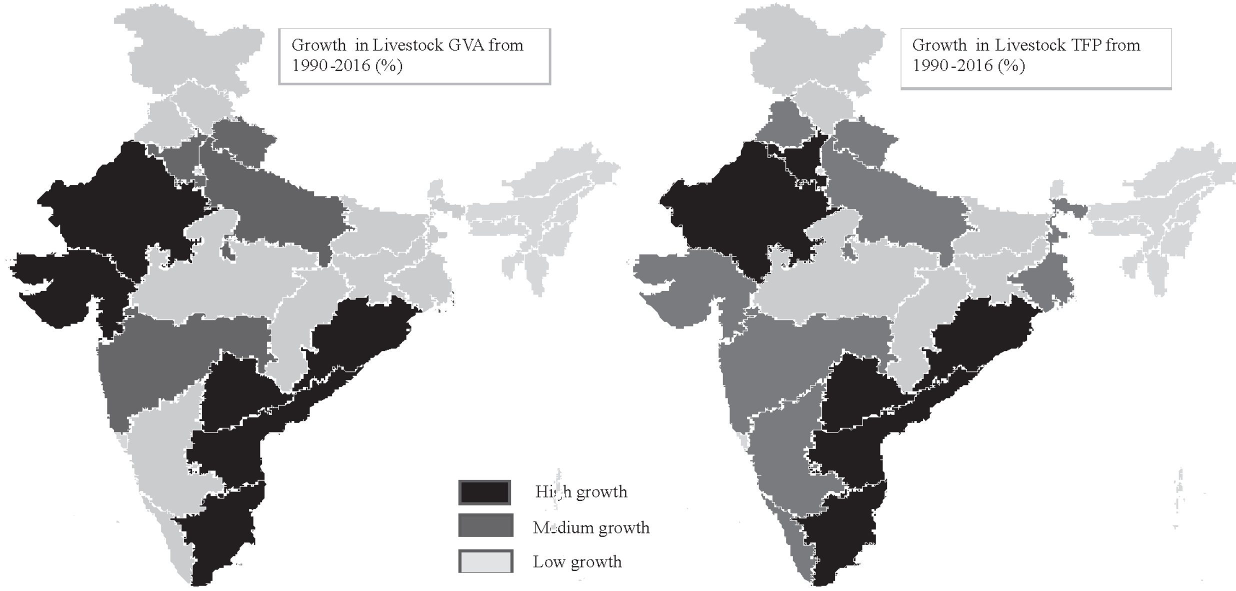

Figure 2 Congruence between growth in livestock GVA and TFP across states

In the eastern India, Bihar performed poorly during the initial period, as is evident from a highly negative growth in TE 1992-93. However, in the later periods, it recovered from sluggish growth to high growth rate of 9% in TE 2015-16. Odisha emerged as one of the top performers in overall growth, but a look at sub-period growth rates paints an altogether different picture. TFP grew at an impressive rate (12.8%) in earlier TE 1992-93 but the growth in later period drastically came down to about 2.5% in TE 2015-16. The declining trend points towards the slower technological development of the sector in recent times. West Bengal has shown positive TFP growth in all the sub-periods (Table 3).

At the national level, the average TFP growth rate in TE 1992-93 was 3.6% which declined to 0.7% in TE 2002-03 later rise to 12.3% in TE 2015-16. Further, it may be inferred from the findings that the TFP in livestock sector in most states has shown improvement over time.

A visual comparison of the states' growth in the livestock gross value added (GVA) and TFP in figure 2 shows a congruence between the two. The states having high TFP growth also have high growth in livestock GVA.

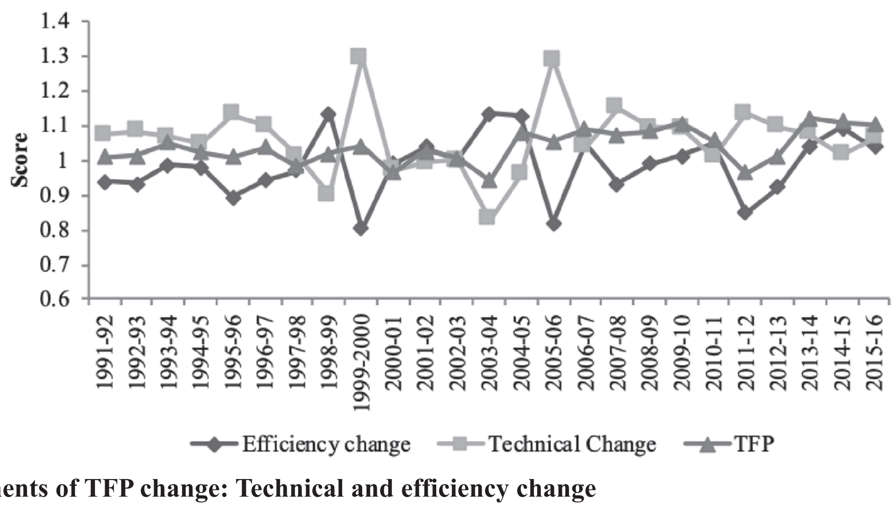

Figure 3 Components of TFP change: Technical and efficiency change

Sources of productivity growth

TFP is not synonymous with technological progress (Kalirajan and Shand 1997). TFP growth can be further decomposed into technical change and efficiency change. The decomposition analysis is essential to understand the sources of productivity growth whether it is a result of technical progress/change or change in efficiency due to improvement in human capital. Efficiency change or efficiency improvement measures the relative deviation of each state from its corresponding frontier. The technical change component measures the overall movement of frontiers over the time period.

The mean efficiency score as well as technical change component have been summarised state-wise in Table 4 and for detailed component wise indices refer Table A3 and A4 in the appendix. The mean efficiency scores for most of the selected states are ≤ 1, revealing either a constant or declining pattern in efficiency component. The technical progress is identified as the main driver of productivity growth in Haryana, Punjab, Rajasthan, West Bengal and Kerala, as is evident from the respective mean technical change score >1 and a constant mean (efficiency score=1). Odisha is the only state where both the components have a mean score of more than 1. All other states have suffered decline in the efficiency, while the technical change recorded a steady growth. Livestock productivity growth at the national level is mainly driven by technical progress (average score 1.057). The technological change is embodied in the form of crossbreeding of local non-descript cattle with exotic germplasm and preventive vaccination. However, the gains obtained from crossbreeding technology have not been evenly distributed across states. Studies also point towards the weak link between research and technology transfer due to the absence of a well-developed extension system for the livestock (Rathod et al. 2018; Abed and Acosta 2018).

Declining efficiency is a serious concern which could be mainly attributed to poor quality feed and fodder availability and high feed prices which alone constitutes about 60-70% cost of milk production. The existing evidence suggests that Indian livestock sector is heavily reliant on agricultural crop residues for their fodder requirement, which doesn't suffice for the nutritional requirement of the animal (Dikshit and Birthal 2010), thus limiting efficiency improvement. Prevalent fodder scarcity makes development and adoption of high yielding and multi-cut hybrids/varieties of fodder a crucial research agenda for livestock development. Some fodder varieties such CSH-20, CSH-24 (suitable for all India) and CoFS-29 (TN and irrigated zone) of sorghum and UPC 628 of cowpea (suitable for northeast, northwest and hilly zone) during Kharif season need wider adoption. Berseem varieties such as: BL-42 (suitable for northern states) and JHB-146 (North West and central zone) and Oats varieties such as: JHO 99-2 (Northwest and northeast zone), RO-19 (all oat growing areas), OL-125 (Northwest and central zone) are suitable during Rabi season. Most of the livestock owners in India are small landholders and require institutional support in terms of credit and proven livestock technology. Poor access to credit discourages adoption of improved technologies and quality inputs. Further, the credit linked insurance scheme although provides protection against risk, it adds to the cost of borrowing (Rajeswaran et al. 2014). Information asymmetry is also one of the constraining factors.

Besides, there are some exogenous factors such as low milk prices and market volatility which might constrain

Table 4 Estimates of technical change and efficiency change in Indian livestock sector-1990-2016

State	Efficiency change	Technical change
Haryana	1.000	1.056
Punjab	1.000	1.048
Uttar Pradesh	0.983	1.056
Himachal Pradesh	0.943	1.067
Jammu &Kashmir	0.935	1.023
Andhra Pradesh	0.988	1.089
Karnataka	0.974	1.067
Kerala	1.000	1.049
Tamil Nadu	0.987	1.101
Bihar	0.980	1.017
West Bengal	1.000	1.039
Odisha	1.040	1.034
Maharashtra	0.966	1.09
Gujarat	0.968	1.068
Rajasthan	1.000	1.059
Madhya Pradesh	0.964	1.054
Mean	0.983	1.057

production efficiency. Milk prices crash have hit the domestic milk market forcing the number of small and marginal dairy farmers to move out of dairy business (Food Sovereignty Alliance, 2017). In 1999, quantitative restrictions placed on skimmed milk powder (SMP) were abolished to abide by WTO regulations, which led to spike in SMP imports causing domestic milk prices to crash. Another major price crash hit in 2015, when SMP exports started rising in the global market, and due to the high price SMP could not be sold resulting in huge domestic build-up of stocks. Emerging threats from transboundary diseases calls for greater financing for animal health, improved monitoring and quarantine system (Otte, Nugent and McLeond 2004).

Conclusions and implications

This study has attempted to estimate the TFP growth in India's livestock sector using a panel dataset of sixteen states from 1990-91 to 2015-16. At the national level, the TFP in India's livestock sector grew at an annual rate of 3.9%. However, there is considerable heterogeneity in TFP growth across states. Punjab, Haryana, Tamil Nadu, Andhra Pradesh, Odisha, Maharashtra and Rajasthan have performed much better on technological front. Jammu & Kashmir, Himachal Pradesh and Bihar rank at the bottom in terms of technological progress. At the national level, TFP growth has been driven by technical change, mainly due to the crossbreeding of non-descript cattle with exotic germplasm and expansion of preventive animal health care. Scale efficiency is estimated at 0.689% indicating the possibility of increasing output by about 30% by adjusting the herd size. There are wide differences in the efficiency levels across states, highlighting the existence of a scope to improve livestock production. These findings suggest increasing of investment in animal science research, linking research outputs to extension systems, improving breeding, feeding and animal health in the lagging states.

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Appendix

Table A1. Summary of changes in annual mean indices

Year	Efficiency change	Technical change	Pure efficiency change	Scale efficiency change	TFP change
1991-92	0.94	1.073	0.976	0.96	1.009
1992-93	0.933	1.086	1.04	0.9	1.013
1993-94	0.987	1.066	0.98	1.01	1.052
1994-95	0.979	1.047	1.002	0.98	1.025
1995-96	0.893	1.133	0.992	0.9	1.012
1996-97	0.942	1.101	0.989	0.95	1.037
1997-98	0.971	1.014	0.996	0.98	0.985
1998-99	1.135	0.9	1.034	1.1	1.022
1999-2000	0.803	1.297	0.949	0.85	1.041
2000-01	0.989	0.972	0.881	1.12	0.962
2001-02	1.036	0.993	0.925	1.12	1.029
2002-03	1.005	1.002	1.026	0.98	1.007
2003-04	1.135	0.831	1.018	1.12	0.944
2004-05	1.128	0.958	1.022	1.1	1.082
2005-06	0.818	1.289	0.967	0.85	1.054
2006-07	1.052	1.039	1.019	1.03	1.092
2007-08	0.932	1.152	0.999	0.93	1.074
2008-09	0.992	1.095	1.003	0.99	1.086
2009-10	1.013	1.093	0.987	1.03	1.107
2010-11	1.046	1.01	1.01	1.04	1.056
2011-12	0.85	1.134	1.033	0.82	0.965
2012-13	0.922	1.099	0.989	0.93	1.013
2013-14	1.04	1.079	0.974	1.07	1.122
2014-15	1.093	1.017	0.997	1.1	1.112
2015-16	1.037	1.064	1.014	1.02	1.104
Mean	0.983	1.057	0.992	0.99	1.039

Table A2 Estimates of Malmquist TFP indices by state

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Haryana	1.115	1.022	1.06	1.005	0.998	1.029	1.034	1.042	1.089	1	1.003	0.988	1.024	0.941	1.051	1.122	1.27	1.072	1.219	1.058	0.931	1.161	1.069	1.225	0.952
Punjab	1.355	0.871	1.254	1.219	1.154	1.062	0.818	1.132	0.906	1.255	1.346	0.882	1	1.044	1.003	1.354	1.046	0.858	1.207	1.017	0.419	1.037	1.798	0.892	1.074
UP	1.044	0.952	0.977	1.027	0.984	1.024	1.061	1.026	1.004	0.936	1.071	0.958	1.03	1.032	1.027	0.993	1.055	1.099	1.121	1.05	1.121	1.019	1.154	1.141	1.103
HP	0.966	0.993	0.984	0.984	0.986	0.989	1.013	1.051	1.054	0.993	1.027	1.112	1.061	0.936	1.052	0.664	0.995	1.216	0.983	0.962	1.216	0.909	1.01	1.037	1.093
J&K	0.621	0.886	0.933	0.9	0.897	0.863	0.909	1.003	1.237	0.725	0.814	1.015	0.93	0.962	0.939	0.905	1.127	1.105	1.208	1.042	0.609	1.371	0.97	1.12	1.28
AP	1.069	1.081	1.183	1.138	0.819	1.139	0.94	0.826	1.631	1.101	1.262	1.22	0.958	1.195	0.964	0.858	1.041	1.058	1.17	1.045	0.749	0.982	1.607	1.137	1.167
Karnataka	0.978	1.06	1.068	1.014	1.05	1.043	1.075	0.961	0.977	1.006	1.01	0.948	0.782	1.048	1.038	0.948	1.215	1.255	0.946	1.11	1.19	1.071	0.956	1.348	1.049
Kerala	1.197	1.194	1.063	1.039	1.111	1.077	0.951	1.374	0.804	1.057	0.96	0.923	0.794	0.804	1.334	0.986	1.206	1.178	1.084	1.019	1.252	1.06	0.991	0.965	1.068
TN	1.23	1.161	0.918	1.075	0.907	1.031	0.941	2.411	0.378	1.009	1.091	1.022	1.027	1.219	1.101	1.262	1.137	1.158	1.258	1.294	1.082	1.077	1.162	1.196	1.059
Bihar	0.529	0.79	1.147	0.915	1.018	1.156	1.051	0.972	1.021	1.016	1.168	0.934	0.769	1.259	1.033	0.872	0.993	1.17	0.994	0.96	1.116	1.085	1.098	1.092	1.08
WB	1.01	1.025	1.072	1.031	1.191	1.125	0.967	0.598	1.589	0.729	0.975	1.358	0.888	1.182	1.112	0.598	1.439	1.135	1.127	1.005	1.097	1.03	1.099	1.102	1.085
Odisha	1.171	1.052	1.163	0.972	1.072	1.077	1.069	1.049	1.023	1.052	1.068	1.033	1.265	1.026	0.967	1.136	1.143	1.208	1.159	1.014	1.092	1.081	1.006	1.045	1.026
Maharastra	1.04	1.127	0.94	1.025	1.03	1.019	1.003	1.029	0.991	1.018	0.972	1.013	1.005	1.003	1.119	1.308	0.98	1.115	1	1.033	1.094	1.044	1.249	1.128	1.162
Gujarat	1	1.171	0.955	1.069	1.075	1.03	0.985	1.005	0.922	1.04	0.962	0.951	0.979	0.987	1.122	1.021	1.132	1.003	1.045	1.154	1.06	1.041	1.025	1.082	1.068
Rajasthan	1.098	0.932	1.182	0.972	1.047	1.016	0.939	1.148	1.034	0.857	0.858	0.9	0.964	1.156	1.351	6.339	0.665	0.892	1.242	1.019	0.382	1.032	1.132	1.22	1.175
MP	1.102	0.99	1.014	1.023	0.952	0.952	1.031	1.003	1.139	0.947	0.822	0.949	0.939	1.042	1.092	0.89	0.949	0.944	1.016	1.167	1.022	1.051	1.04	1.142	1.274

Table A3 Estimates of Efficiency by state

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Haryana	1	1	1	1	1	1	1	1	1	0.951	1.055	0.973	1.025	1	0.946	1.057	1	1	1	1	1	1	1	1	1
Punjab	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
UP	0.97	0.782	0.961	0.966	0.869	0.927	0.982	1.049	0.81	0.917	1.129	1.02	1.267	1.113	0.808	0.952	0.926	1.083	1.074	1.014	0.997	0.905	1.076	1.116	1.024
HP	0.918	0.781	0.956	0.931	0.865	0.89	0.945	1.061	0.824	0.946	1.015	1.136	1.277	1.013	0.778	0.589	0.846	1.145	0.955	0.991	0.844	0.967	0.972	1.167	1.024
J&K	1	1	1	1	0.902	0.782	0.841	1.027	0.996	0.715	0.861	1.085	1.15	1.088	0.703	0.806	0.972	0.846	1.061	1.013	0.515	1.111	0.939	1.135	1.218
AP	0.772	1.016	0.979	1.068	0.745	0.991	0.836	0.818	1.332	1.014	1.224	1.246	1.152	1.294	0.685	0.719	0.871	0.988	1.131	1.074	0.642	0.888	1.631	1.127	1.077
Karnataka	0.762	0.92	0.923	0.922	0.978	0.912	0.99	0.968	0.763	0.991	1.084	1.022	0.991	1.153	0.772	0.917	1.028	1.193	0.92	1.151	0.766	1.139	0.921	1.494	0.968
Kerala	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TN	0.889	1.091	0.76	1.008	0.825	0.897	0.837	2.388	0.301	0.917	1.114	1.043	1.239	1.292	0.782	1.086	0.967	1.087	1.195	1.252	0.821	0.915	1.129	1.165	0.98
Bihar	0.746	0.654	1.189	0.84	0.957	1.02	1.265	1.042	0.764	1.035	1.265	0.938	0.934	1.485	0.835	1.044	0.833	1.153	0.926	0.978	0.946	0.997	1.022	1.031	0.97
WB	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Odisha	1.187	1.004	1.096	0.941	0.695	1.019	1.085	2.62	0.428	2.465	1.05	0.646	0.917	1.34	0.672	1.874	1	1	1	1	1.011	1	0.989	1	1
Maharastra	0.87	0.952	0.871	0.974	0.908	0.946	0.972	1.039	0.772	0.955	1.008	1.046	1.05	1.316	0.783	1.08	0.82	1.001	0.921	1.004	0.912	1.02	0.905	1.085	1.093
Gujarat	0.847	0.993	0.875	1.027	0.94	0.923	0.922	1.015	0.733	1.082	0.942	1.012	1.177	0.798	1.237	0.959	0.968	0.955	1.008	1.167	0.891	0.91	0.981	1.016	0.982
Rajasthan	1.145	0.922	1.265	0.973	0.907	0.938	0.944	1.204	0.869	0.865	0.839	0.946	1.236	0.809	1.419	3.876	0.905	0.66	1.076	0.945	0.326	0.86	1.106	1.173	1.105
MP	1.064	0.917	1.03	0.977	0.825	0.863	0.995	1.017	0.909	0.998	0.806	1.016	1.18	0.814	1.163	0.836	0.816	0.897	0.981	1.196	0.805	0.906	0.997	1.079	1.198

Table A4 Estimates of technical change by state

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Haryana	1.115	1.022	1.06	1.005	0.998	1.029	1.034	1.042	1.089	1.051	0.951	1.016	0.999	0.941	1.111	1.061	1.27	1.072	1.219	1.058	0.931	1.161	1.069	1.225	0.952
Punjab	1.355	0.871	1.254	1.219	1.154	1.062	0.818	1.132	0.906	1.255	1.346	0.882	1	1.044	1.003	1.354	1.046	0.858	1.207	1.017	0.419	1.037	1.798	0.892	1.074
UP	1.075	1.217	1.017	1.064	1.132	1.105	1.08	0.978	1.24	1.021	0.949	0.94	0.814	0.927	1.272	1.043	1.139	1.015	1.044	1.035	1.125	1.126	1.072	1.023	1.077
HP	1.053	1.272	1.029	1.057	1.14	1.111	1.072	0.99	1.278	1.05	1.012	0.979	0.831	0.923	1.351	1.129	1.176	1.062	1.03	0.971	1.44	0.94	1.038	0.888	1.067
J&K	0.621	0.886	0.933	0.9	0.995	1.104	1.081	0.976	1.242	1.014	0.946	0.936	0.809	0.884	1.336	1.124	1.159	1.306	1.139	1.028	1.183	1.234	1.033	0.987	1.051
AP	1.384	1.064	1.208	1.066	1.099	1.149	1.125	1.009	1.224	1.086	1.031	0.979	0.831	0.923	1.409	1.194	1.195	1.071	1.034	0.973	1.166	1.106	0.985	1.009	1.083
Karnataka	1.283	1.153	1.158	1.099	1.073	1.143	1.085	0.993	1.279	1.015	0.932	0.928	0.789	0.909	1.344	1.035	1.183	1.052	1.028	0.965	1.553	0.941	1.038	0.902	1.084
Kerala	1.197	1.194	1.063	1.039	1.111	1.077	0.951	1.374	0.804	1.057	0.96	0.923	0.794	0.804	1.334	0.986	1.206	1.178	1.084	1.019	1.252	1.06	0.991	0.965	1.068
TN	1.384	1.064	1.208	1.066	1.099	1.149	1.125	1.009	1.255	1.1	0.98	0.979	0.829	0.943	1.409	1.162	1.176	1.065	1.053	1.034	1.319	1.178	1.03	1.027	1.08
Bihar	0.71	1.208	0.965	1.089	1.065	1.134	0.83	0.933	1.336	0.981	0.923	0.996	0.823	0.848	1.238	0.835	1.192	1.015	1.074	0.981	1.18	1.088	1.074	1.059	1.114
WB	1.01	1.025	1.072	1.031	1.191	1.125	0.967	0.598	1.589	0.729	0.975	1.358	0.888	1.182	1.112	0.598	1.439	1.135	1.127	1.005	1.097	1.03	1.099	1.102	1.085
Odisha	0.986	1.048	1.061	1.033	1.542	1.057	0.985	0.4	2.389	0.427	1.017	1.599	1.379	0.766	1.439	0.606	1.143	1.208	1.159	1.014	1.081	1.081	1.016	1.045	1.026
Maharastra	1.196	1.183	1.079	1.052	1.135	1.077	1.032	0.991	1.283	1.066	0.964	0.969	0.957	0.762	1.43	1.212	1.195	1.113	1.086	1.029	1.2	1.024	1.38	1.04	1.064
Gujarat	1.181	1.18	1.092	1.04	1.143	1.116	1.068	0.99	1.259	0.962	1.022	0.939	0.832	1.236	0.907	1.065	1.17	1.051	1.037	0.989	1.19	1.143	1.045	1.065	1.088
Rajasthan	0.958	1.011	0.934	0.999	1.155	1.084	0.994	0.954	1.189	0.99	1.023	0.951	0.78	1.429	0.952	1.635	0.734	1.353	1.154	1.078	1.173	1.2	1.024	1.04	1.064
MP	1.036	1.08	0.985	1.048	1.154	1.103	1.037	0.986	1.253	0.949	1.02	0.935	0.796	1.28	0.939	1.065	1.163	1.053	1.035	0.976	1.269	1.16	1.043	1.059	1.064

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Can forage technologies transform Indian livestock sector?: evidences from smallholder dairy farmers in Bundelkhand region of central India

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Abstract The study has analysed the factors affecting adoption of improved forage technologies and its impact on milk yield and feed sufficiency in Bundelkhand region. We used propensity score matching (PSM) technique on cross-sectional data collected from 400 dairy farmers for impact evaluation and also conducted sensitivity analysis to examine the effect of uncontrolled confounders on the estimands. Our findings suggest that, education status, standard livestock unit, animal breed type, off-farm income activities, farm size and access to training, credit and market significantly influence adoption of improved forage technologies and practices. Further the adoption led to a significant increase in annual milk production (over 950 litres) and daily milk yield (1.15 to 2.04 litres) and also reduced time spent in feeding by around 2 hours during *zaid* season and around an hour during *kharif* season.

Keywords Forage technologies, milk productivity, feed sufficiency, PSM, Bundelkhand

JEL Codes Q12, Q16, R58

India has the largest livestock population but of low productivity (Choudhary et al. 2020). Inadequate supply and poor quality of feeds and fodders is one of the major factors for low animal productivity (Ghosh et al. 2016). Feed is also a major cost in dairy production (Mahanta 2017). In India, land allocation to cultivation of green fodder crops is limited and has hardly ever exceeded 5% of the gross cropped area. Therefore, the supply of feed and fodder has always remained short of normative requirement (Ramachandra et al. 2007, Satyapriya et al. 2012), restricting the realization of the true production potential of livestock (Dikshit and Birthal 2010). Presently, the country faces a net deficit of 11.24% in green fodder, 23.4% in dry crop residues and 28.9% in concentrate feed ingredients (Roy et al. 2019).

Nonetheless, there exist regional and seasonal disparities in fodder production. Most of the deficient regions lie in the arid and semi-arid regions. Seasonality in forage availability accentuates the cost of feed and thus the profitability of the livestock production (Gachuiri et al. 2017). Moreover, seasonal scarcity of forages puts additional pressure on common property resources, particularly in the arid and semi-arid tropics; and has always added to the drudgery of farm households especially women in terms of time and energy spent for fodder collection (Dhyani et al. 2013). Therefore, ensuring quality and reliable availability of year-round fodder is prerequisite for enhancing productivity.

One of the main approaches for addressing the feed scarcity has been to develop and promote adoption of improved year-round forage options that include a wide varieties of sown or planted grasses, and herbaceous or dual-purpose cereals and legumes. Integration of forages into mixed cropping systems has been reported to generate significant benefits (White et al. 2013, Paul et al. 2020).

In India, research and development programmes on forages over the past five decades have spread over time and regions. Several experimental field trials have shown the potential of integrating improved forages in enhancing livestock productivity (Sharma et al. 2007, Ghosh et al. 2016); yet comprehensive and quantitative evidences on the driving factors of the adoption of forage technologies and their multidimensional impacts, are lacking in the Indian context.

The present study, therefore, using the example of the KISAN MITrA[1] (Knowledge-based Integrated Sustainable Agriculture Network Mission India for Transforming Agriculture) project seeks to fill the literature gaps on the socio-economic and institutional factors affecting adoption of improved forage technologies and the impacts of forage based interventions on milk yield and feed sufficiency. Under the KISAN MITrA project, a broad set of improved forage technologies and practices like use of quality fodder seeds, grasses on bunds, cultural practises of fodder production and conservation, and ration balancing programmes were promoted making it an ideal context for an investigation of the aforementioned farm-level adoptions and impact analysis of forage based interventions.

Material and methods

Study area

This study was conducted in Lalitpur district located in Bundelkhand region of central India (Fig. 1). Most of the population is dependent on crop/livestock-based activities and around one-third of the geographical area is covered by degraded forests, permanent pastures, fallows and wastelands. Dairy and goat farming are important in the region. The district receives average annual rainfall of around 880 mm, of which 90% occurs in *kharif* season (June-October).

Three villages namely *Birdha, Purakhurd, Jhabar* located in Talbehat block of Lalitpur district were the treated villages in our study as all the project activities were focussed within the physical boundaries of these villages. Simultaneously, three contiguous villages namely *Gundera, Gebra and Viharipura* were identified as control villages, with no forage based interventions, but having close similarity with treated villages in their agro-climatic, infrastructural and socio-economic set up. This criterion has been considered in other impact assessment studies to control for any influence (bias) resulting from close proximity with adopters (Gitonga et al. 2013, Marwa et al. 2020).

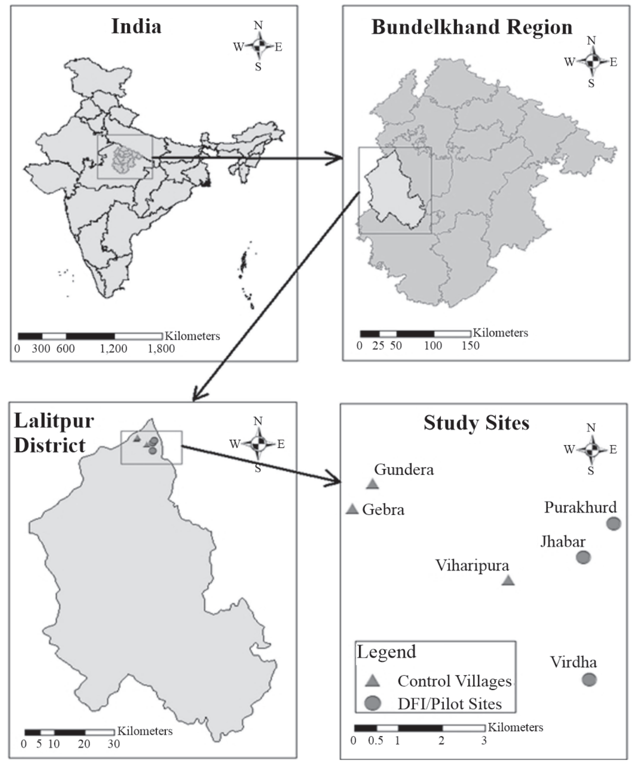

Figure 1 The locale of the study area delineating treated and control villages

Analytical framework

Drivers of adoption of improved forage technologies and practices

Following the theory of expected utility, we assumed

[1]The KISAN MITrA project, funded by government of Uttar Pradesh State (India), was started in the Bundelkhand region of India in 2017 by ICRISAT Development Center (IDC), Hyderabad in partnership with ICAR-Indian Grassland and Fodder Research Institute (IGFRI), Jhansi, and ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi. One of important objectives of the project was to implement improved forage technologies on farmer's field for ensuring year-round quality fodder for livestock.

that a farmer's adoption decision given the risk and uncertainty prospects, is based on the comparison of expected utility (Mercer 2004). Farmers will adopt and practise the interventions if the expected utility from adoption (Ua) is greater than that derived from non-adoption (Un). Profit is used as a proxy and if combined with attitude to risk, farmers are described as maximizing the expected utility of profit rather than expected profit (Borges et al. 2015).

The utility derived from the adoption of improved forage based technology will have a binary choice component determined by observable characteristics X_i and a stochastic error term ε_i.

$I_i^* = \beta X_i + \varepsilon_i$; $I_i = 1$, if $I^* > 0$, and 0 if otherwise

Where, I_i is a dichotomous variable for the adoption of the forage technologies and β is a vector of parameters to be estimated.

Farmers will adopt forage technologies if $I_i^* = Ua - Un > 0$. The probability of adopting the technologies can then be estimated as follows.

$\Pr(I_i = 1) = \Pr(I_i^* > 0) = 1 - D(-\beta X_i)$

Where, $\Pr(I_i = 1)$ is the probability of adoption and D represent the cumulative distribution function for ε_i.

Impact assessment

An empirical challenge in assessing causal impact is to examine the outcome and its counterfactuals (Holland 1986). Ideally, the solution for this would be to randomly assign the treatment (forage interventions in the present case) among farmers, i.e. randomized control trial (RCT), however it is not feasible to implement it practically. Therefore, we relied on Propensity Score Matching (PSM) method, a quasi-experimental technique which is widely used in impact assessment studies to deal with the problem of the missing counterfactual (Imbens and Wooldridge 2009).

The first step in PSM is to estimate the predicted probability values of adoption (propensity scores) using the probit or logit model. We used the standard probit model (0=untreated and 1=treated) to obtain propensity score (Rosenbaum and Rubin 1983).

$P(X_i) = P(Z=1|X_i)$

Where, $P(X_i)$ is the propensity score of the i^{th} household; $P(Z=1|X_i)$ indicates the probability of treatment given the observable covariates (X) of i^{th} household.

To ensure that there is no systematic difference in the covariates of treated and control groups in the matched sample, the balancing test was conducted. After that, three matching algorithms namely nearest neighbour matching (NNM), kernel based matching (KBM) with bandwidth 0.01 and radius matching (RM) with caliper 0.1 were employed. Though these matching procedures differ in creating the counterfactuals and assigning weights to the neighbours, and have their own limitations; using all the three methods provides robustness check of the results.

Finally, the impact of adoption of improved forage technologies on outcome variables indicated by the average treatment effect on the treated (ATT) which is computed by restricting the matches to the households with propensity scores that fall in the area of common support (Caliendo and Kopeinig 2005):

$ATT = E\{Y1_i - Y0_i\}$

Where, E(Yi) denotes the expected value of the i^{th} outcome variable; 1 represents the treated, 0 otherwise.

We also conducted sensitivity analysis using bounding sensitivity method proposed by Rosenbaum (2002) for the ATT that are significantly different from zero to test whether inference regarding impact were sensitive to 'hidden bias' due to unobservables.

Data

Matching technique requires more observations from control units, preferably in the ratio of around 1:2 (Datta 2015). Hence, we collected information from 150 farm households from the treated villages and from 250 households from control villages. Households were stratified based on land size, and then probability proportional to size method was used to draw sample households from each village. Finally, the respondent household-heads were selected by using random sampling technique.

The primary data collected from transect walk observations, interviews of key informants and detailed household surveys. A team of local enumerators ,who are well acquainted with farming practises in the area, culture, and language of the local inhabitants ,were recruited and trained for data collection. The survey schedule (administered in Hindi for convenience purpose) captured information on various socio-economic, farm-specific and institutional support parameters for the agricultural year 2019-20.

Results and discussion

Covariates and descriptive statistics

Household is the ultimate clientele of farm technology; hence household characteristics like household size, education status and experience in farming are important parameters to be considered in adoption process (Noltze et al. 2013, Ghimire et al. 2015). Further, farm characteristics and institutional factors have also been reported as key influential factors in technology adoption process (Maina et al. 2020). Table 1 depicts the definitions and summary statistics of the selected variables.

It is evident that the households from the treated (adopters) and control villages (non-adopters) are systematically different in of many observed characteristics (Table 1). For instance, relative to control villages, household-heads of treated villages are better educated and have a larger land holding. Moreover, adopters had on average standard livestock

Table 1 Definitions and sample averages of selected variables

Variables	Description	Control (C, n=250)	Treated (T, n=150)	Mean difference (C – T)
	Households characteristics			
Age of HH	Age of household head (years)	47.65	46.63	1.02
HH_Male	% of household headed by male	95	94	1
Experience_HH	Experience of household head in farming (years)	27.63	26.83	0.80
Education_HH	Numbers of years of schooling by household head	3.62	5.27	-1.654**
HH Size	Household size (No.)	6.00	6.19	-0.19
Dependency Ratio	(Household members < 15 and > 65 years)/ household size	0.38	0.35	0.03
	Farm characteristics			
Land holdings	Operational holding in hectares	1.57	1.97	-0.40**
LSU	Standard Livestock unit	3.08	4.16	-1.08*
Buffalo to IC ratio	Buffalo to Indigenous Cattle ratio in dairy herd	0.47	0.69	-0.22*
Off-farm activities	% of household involved in off-farm income activities (%)	37.23	53.45	-16.22*
	Institutional characteristics			
Training	% of households exposed to training and demonstration visit	67.29	93.13	-25.84*
Credit	% of households that has access to farm credit	45.21	49.30	-4.09
Market access	% of households that are able to sale surplus milk	47.36	66.41	-19.05*
	Outcome indicators			
Annual milk production	Total milk production per household per year (litres)	1898.23	2934.28	-1036.05**
Cow productivity	Average milk production (per day per cow)	2.06	3.29	-1.23*
Buffalo productivity	Average milk production (per day per buffalo)	4.81	6.24	-1.43*
Feeding time_Kharif	Daily hours dedicated to feeding during *kharif* season (June to October)	3.14	1.82	-1.25*
Feeding time_Rabi	Daily hours dedicated to feeding during *rabi* season (November to March)	2.15	1.89	-0.26
Feeding time_Zaid	Daily hours dedicated to feeding during *zaid* season (April to May)	4.00	2.07	1.94*

*p<0.01, **p<0.05

Table 2 Indicators of matching quality before and after matching

Test	Before matching	After matching		
		NNM	KBM	RM
Pseudo R^2	0.241	0.002	0.013	0.029
LR χ^2 (P-value)	61.17* (0.00)	4.17 (0.79)	3.26 (0.62)	6.32 (0.59)
Mean Standardized Bias	29.71	7.10	5.90	9.16
Total Bias reduction (%)		76.10	80.14	69.16

Source Authors' estimates based on survey data

unit (LU) of 4.16 units, which is significantly higher than for non-adopters (3.08 units).

Larger proportions of households in the treated village (53.45%) derive income from off-farm sources. Further, adopters are better exposed to training and demonstrations. Consequently, a significant proportion of adopters (66.41%) are able to sell surplus milk.

The significant differences in outcome indicators clearly indicate that adopters of improved forage technology are systematically better off than their non-adopters counterpart in terms of milk yield and daily time spent in sourcing feed during *rabi* and *zaid* cropping seasons (Table 1).

However, as the effects of confounders have not been controlled for, it would be inappropriate to draw any inference regarding the impact of adoption of forage based interventions on these indicators. This further necessitates matching through PSM to analyze factors influencing adoption and to estimate impact thereof.

Matching quality and balancing test

Before discussing the drivers of adoption and its impact, we underline here the quality of the matching through all three algorithms, as the success of PSM lies in matching the observable covariates across treated and control groups (Becerril and Abdulai 2009). Conforming to the requirement of balancing test, the Pseudo R^2 drops significantly to 0.2, 1.3 and 2.9% for NNM, Kernel (KBM) and Caliper matching (RM) respectively, from around 24% before matching (Table 2).

The higher and significant likelihood-ratio (LR) before matching signifies the presence of systematic differences between the treatment and comparison groups. The insignificant p-value for LR after matching indicates that these differences have been removed making the two groups comparable.

Further, the matching procedure led to substantial reduction in bias (69.16-80.14%) and as per the prerequisite criteria (Rosenbaum and Rubin 1983) the Mean Standardized Bias (MSB) is well below 20% after matching. The low Pseudo R^2, insignificant p-values of the LR test, low MSB suggest that the specification of propensity is successful in terms of balancing the distribution of covariates between treated and control groups.

The distribution of propensity scores and region of common support through all the three matching algorithms are depicted in Fig 2. Suitable matches of adopters (treated) and non-adopters (control) are shown as 'treated on support' while, adopters with bad matches from among the control are termed as 'treated off support."

Visual observation of the Fig 2 clearly indicate that there is considerable overlap of the distributions of the propensity scores for adopters and non-adopters of improved forage technology after matching suggesting that the assumption of common support firmly holds.

In case of NNM all the observations from treated unit find a good match and thus there are no treated off-support observations (Fig. 2a). However, in KBM and RM techniques few observations are treated off-support and thus discarded during the analysis (Fig. 2b & 2c). The matching procedure created a clean counterfactual as none of the mean differences of the selected variables between treated and control group are statistically significant (Table 2).

Determinants of improved forage technology adoption

Table 3 presents the probit results on matched sample. Concerning the household characteristics, we find that

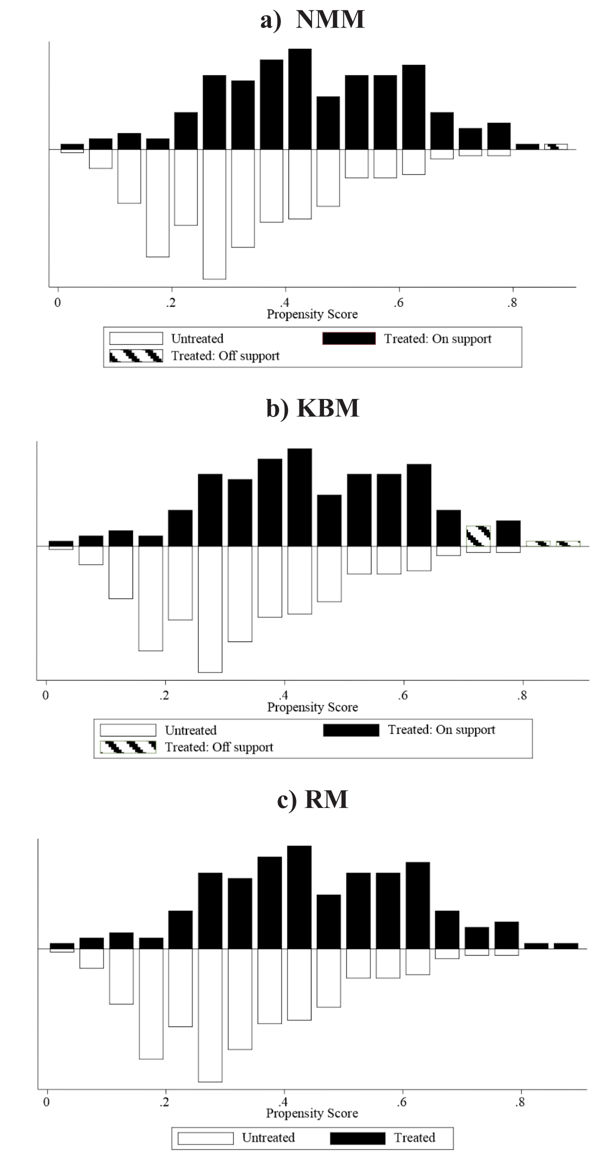

Figure 2 Propensity score distribution and common support

Table 3 Regression results from probit model on matched sample# for the driving factors of adoption of improved forage technologies/practices

Variables	Coefficients	Std. error	Marginal effect
Age of HH	0.032	0.073	0.0083
HH_Male	0.078	0.139	0.0018
Experience_HH	-0.019	0.027	-0.0037
Education_HH	0.371*	0.016	0.0610
HH Size	0.0071	0.0273	0.0029
Dependency Ratio	-0.1741*	0.0331	-0.0763
Land holdings	0.2382*	0.0914	0.0413
LSU	0.082*	0.0173	0.0991
Buffalo to Cattle ratio	0.6831*	0.2976	0.1329
Off-farm activities	0.0247**	0.0109	0.0571
Training	0.6179*	0.1186	0.2312
Credit	0.3951*	0.1049	0.0361
Market access	0.329*	0.0791	0.1137
Log likelihood	-241.36		
LR χ^2	49.71*		
Sample size†	328		

Source Authors' estimates based on survey data
Note *p<0.01, **p<0.05
† KBM resulted into 150 and 178 observations from treated and control samples respectively, making total sample size of 328.
# We also used NMM and Calliper matching methods, and the results were similar to KBM based estimates. Hence, in the interest of time and space, we present results for KBM method only.

adoption is positively associated with longer formal schooling of the household head. The learning chances of educated farmers from exposure to technical advice, training and farm demonstrations may be higher. The direct relation between inclination towards adoption of improved agricultural technologies and education of household head has good literature support (Kumar et al. 2020). Additionally, households with large farm size are 4% more likely to adopt the improved forage technologies. The larger landholdings accentuate the household's ability to take risks and thus increase the probability of adoption of new technology (Kabir and Rainis 2015).

Unsurprisingly, households with higher livestock units and having more buffaloes in their herd are more likely to adopt improved forage based interventions - the probability increases by 0.099 and 0.132, respectively. The finding is in congruence with Kanyenji et al. (2020) and Maina et al. (2020) who observed that households with higher livestock units utilized more crop residue as animal feed and thus more likely to adopt agricultural technologies that yield more forages. Kassie et al. (2018) also reported that ownership of productive breeds increases demands for feed. Moreover, a positive and significant association between off-farm income and the probability of adoption of improved forage technologies was observed. Off-farm income relaxes liquidity constraints faced by the farm households and induces increased use of improved seeds (Diiro 2013, Choudhary and Singh 2019). A significantly higher adoption intensity of agricultural technology among households with off-farm income relative to their counterparts without off-farm income is well acknowledged (Mwangi and Kariuki 2015).

All the three instructional factors considered in this study viz., training, credit and market access have a positive and significant effect on adoption of forage technologies. Exposure to training and demonstrations on improved forage practises increases the probability of adoption by 0.23. Training and demonstrations boost credibility among farmers towards new technologies and counter balance the negative effect of lack of formal education in the adoption decision.

A positive relationship between extension and training, and technology adoption among farm households has been unanimously supported in previous studies (Kumar et al. 2020, Maina et al. 2020). Additionally, access to formal credit and output market is correlated with household's-risk bearing ability and stimulates technology adoption (Ghimire et al. 2015). In the present study, we observed that due to the absence of efficient milk collection centre in the region, the milk vendors or middle men have strong presence for milk marketing, and farmers do not realise remunerative price. However, few farmers disposes the surplus milk in form of dairy products like *Ghee* (clarified butter made from the milk) and *Khoa* (highly condensed milk), which undoubtedly fetches higher prices but also involves considerable drudgery and processing costs.

Impact of forage technologies adoption

The estimated causal impact of improved forage technologies, as average treatment effect on the treated (ATT), on selected outcome variables are presented in Table 4. The estimates of different matching algorithms are though quantitatively different, but qualitatively these are similar. These estimates control for the farmers' endogenous decisions on participating in the KISAN MITrA project and whether to adopt improved forage technologies.

We find that ATT is positive and statistically significant for most of the outcome variables. With regard to annual milk production, adopter households had a higher annual milk yield than non-adopters with matched characteristics and the treatment impact was over 950 litres. The corresponding annual gross return was estimated to hovers between INR 38000 to INR 39000 (Table 5). The impacts on milk yield differ across dairy breeds. While the daily milk yield of cows significantly increased by 1.15 to 1.97 litres; for buffaloes, the improved forage feeding raised daily milk yield by 1.23 litres to around 2 litres.

The assessment of the ATT of adoption improved on feed sufficiency revealed that the project interventions in the study area are associated with increased feed availability, particularly during feed stress periods. After matching, compared to the non-adopters the daily time spent by the adopters in sourcing feed significantly reduced by around 2 hours during the *zaid* season and around an hour during *kharif* season.

The establishment of perennial fodder grasses by the adopters in their forage plots was key sources of cut-

Table 4 Estimates of ATT: Impact of forage technologies

Outcome indicator	Average treatment effect on the treated			Gamma
	NNM	KBM	RM	(Γ)
Total milk production per household per year (litres)	977.13**	959.54**	951.39*	1.25-1.30
	(467.11)	(477.38)	(423.32)	
Cow's daily milk productivity	1.97*	1.15*	1.25*	1.80-1.85
	(0.71)	(0.342)	(0.43)	
Buffalo's daily milk productivity	2.04*	1.23*	1.47*	2.15-2.20
	(0.81)	(0.272)	(1.34)	
Daily hours spent to feeding (*kharif* season)	-1.12*	-1.05*	-0.95**	1.35-1.40
	(0.16)	(0.25)	(0.21)	
Daily hours spent to feeding (*rabi* season)	-0.41	-0.39	-0.37	–
	(0.29)	(0.26)	(0.21)	
Daily hours spent to feeding (*zaid* season)	-1.80*	-1.89*	-1.79*	1.20-1.25
	(0.19)	(0.26)	(0.21)	

*p<0.01, **p<0.05

Note Figures in parentheses indicates standard error

Table 5 Economic benefits of improved forage technologies

Parameters	Economic Gains (INR)		
	NNM	KBM	RM
Annual gross returns* due to increased milk production	39085.2	38381.6	38055.6
Daily gross return per cow	78.8	46.0	50.0
Daily gross return per buffalo	81.6	49.2	58.8
Reduced imputed labour cost (*zaid* and *kharif* season)†	10350.00	10158.75	9371.25

*Gross margin was calculated using milk procurement price (= INR 40/litre) in the study area.

†Imputed labour cost was calculated considering the prevailing labour cost of INR300 for 8 working hours in the study area.

and-carry grass during the *zaid* and *kharif* seasons that saved significant time in sourcing feed than non-adopters that reported spending around 3 to 4 hours sourcing green fodders, mainly weeds and shrubs, from fields and distant areas on a daily basis. In monetary terms, the feed sufficiency due to the project interventions benefited the adopters by reducing the imputed labour cost by around INR 10,000 (Table 5). We did not find significant impact on time saving in sourcing feed during *rabi* seasons due to the plenty availability of traditional feed sources such as crop bi-products and crop residues in these seasons. Our results are consistent with the findings of Ashley et al. (2016) from Cambodia and Maina et al. (2020) from Kenya, who noted that adoption of improved forage technologies resulted in a significant reduction in time spent in sourcing for feed during dry periods.

The result of sensitivity analysis to examine the effect of uncontrolled confounders is also reported in Table 4 (col. 5). The values of critical level of hidden bias (Γ) are well within the acceptable range (Mendola 2007, Keele 2010) and ranged between 1.20–1.25 to 2.15-2.20. The value of Ã for daily hours spent for feeding during *zaid* cropping season (1.20–1.25) implied that the credibility of a positive impact of adoption on feed sufficiency during the dry season would be questioned if households with similar characteristics differed in their odds of adoption by even 20-25%. The higher the value of Γ, the lower the hidden bias would be and the converse is also true. Therefore, we can conclude that the inference on estimated impact on milk productivity will not be changed even in the presence of large amounts of uncontrolled heterogeneity. In other words, impact of improved forage technology adoption on milk yield of dairy animals is less sensitive to the unobserved bias.

Conclusions

The present study has empirically analysed the drivers as well as farm-level impacts of adoption of improved forage technologies promoted under KISAN MITrA project in Bundelkhand region of central India. We established that the adoption of improved forages is positively influenced by level of education of household head and, various farm and institutional characteristics in a significant way. This necessitates a holistic approach for promoting the uptake of improved forage practises by livestock keepers.

Improving education status of farmers can go long way as it also have multiplier effect on economy, therefore strengthening public education system in rural areas should be the prime policy focus. Besides, mainstreaming practically oriented, participatory and interactive model like farmer field school (FFS) program and encouraging frontline demonstrations by local research institutes, to impart training to the dairy farmers on improved fodder production, conservation and utilization would be imperative to improve farmers' capacity and skills in forage and dairy management.

An urgent policy need in the studied region is to ensure parallel development of supporting market environment for surplus milk encompassing backward and forward market linkages. Promoting farmer's coalition through farmer producer organizations (FPOs) would be crucial in this direction for safeguarding the interest of small dairy farmers. Further, strengthening and streamlining the rural credit networks and other service providers who offer market and input support to dairy farmers will also be a key intervention for increasing the uptake of improved forage technologies.

The kind of rigorous econometric analyses used in this study is crucial for understanding the actual field-level impacts of various sets of improved forage technologies and practices on milk productivity and socio-economic welfare of dairy farmers. Finally, the evidence from Bundelkhand region, with its typical agro-ecological conditions characterized by undulating topography and unique climatic challenges, can offer important lessons for the promotion of improved forage technologies for improving livestock productivity in arid and semi-arid regions around the world which face similar challenges. However, integrating farmer's choices with the suggested policy interventions will be more imperative as the ground implementation of strategies eventually governed by many socio-economic factors prevailing in a region.

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The role of the macro environment and firm-specific characteristics in improving the resource use efficiency of the Indian food processing industry

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Abstract This paper estimates the resource use efficiency of the Indian food processing industry and investigates the factors that explain the possible variations in the resource use efficiency across firms and over time. Findings from the four-stage semi-parametric DEA analysis indicate low resource use efficiency because of both macroeconomic conditions and firm-specific characteristics. The results have significant implications for the food processing industry in promoting the industry in the longrun. Emphasis on regional policy, managerial decisions and efforts to improve the working capital turnover with consideration to quality standards are vital.

Keywords Resource use efficiency, Food processing industry (FPI), Semi-parametric four-stage DEA

JEL Codes D61, G14, L11, L25

Expansion of the food processing industry (FPI) can have a multiplier effect on the Indian economy. The industry generates employment in the rural non-farm sector and can absorb surplus harvest to minimize the post-harvest losses to stabilize farm income. The need for this sector's progress is further driven by the rise in per capita income and changing consumption patterns, particularly in the middle and high-income groups (Bhalla and Hazell 1998, Chenggapa et al. 2004). More importantly, reorientation of the global trade towards high-value commodities from the primary food articles is perceived as most beneficial to the country's growth (Gopinath et al. 1996). On the other side, the opportunities in terms of large and diverse products of food grains and other high-value commodities such as milk, fruits and vegetables have not been exploited to their potential and there exists a significant amount of wastage due to post-harvest losses (Jha et al. 2015). Also, the low level of processing has not contributed much to the global demand for processed foods. Thus, the industry has a tremendous opportunity to grow within India and globally. Having a strong linkage with agriculture and dealing with highly perishable commodities, the sector requires different operational mechanisms and policy support. While the sophistication of the food industry is expanding with the rising demand for quality and nutritional food, the up-gradation of technology and raising productivity are crucial in the Indian context.

Understanding productivity growth and its drivers, particularly in the industrial sector in India, has been the key area of interest for researchers. These studies, however, have mostly been confined to manufacturing (Chand and Sen 2002, Krishna and Mitra 1998, Goldberg et al. 2010, Goldar and Kumari 2003, Goldar et al. 2019) and a few studies focused on the food industry, which revealed that the growth of the Indian food processing industry was mainly constrained due to low technical efficiency (Ali et al. 2009, Kumar and Basu 2008). Thus, there is a dearth of studies on resource use efficiency and associated factors at the disaggregated level. This paper is an attempt to examine the resource use efficiency of the Indian FPI using firm-level data. The paper also investigates the factors at the macro and micro levels that affect the resource use efficiency across firms and over time.

Data and methods

Data

To know the pattern of input-use at the industry-level, the data on fixed capital, number of workers, material cost, and fuel and electricity cost along with the gross value added (GVA) for 1980-2018 were compiled from the Annual Survey of Industry (ASI), Ministry of Statistics and Programme Implementation (MOSPI), Government of India (GoI). Output and input values were deflated at 2011-12 constant prices by Wholesale Price Index (WPI) available from the Office of Economic Adviser (OEA), Ministry of Commerce & Industry (MOC&I), GoI. Trends in the factor intensity for the FPI and sub-sectors are noticed through the ratio of input to output. To analyse the input use efficiency and its correlates, we use semi-parametric four-stage Data Envelopment Analysis (DEA). The firm-level panel was constructed by developing algorithms based on the opening and closing value of the fixed asset to link the firms in successive years. To begin with, in the first stage, two alternative models were specified. In the model I, we used fixed capital and workers' man-days as inputs and in model II, plant and machinery cost, cost of building and workers' man-days were considered. These models capture the use of capital that brings efficiency to the firm mainly from technology and its appropriate use. Estimating the alternative model helps us to get more accurate and robust measures of efficiency. Like any other sector, the food industry is also not the exception to the macroeconomic business environment that affects resource use patterns. To ascertain this, in the second stage, we specify the following three variables in the Stochastic Frontier Analysis (SFA) that broadly capturers the macroeconomic influence on each firm at the industry level. We include State Domestic Product (SDP) growth rate to capture the different policy environments under which the firms operate. SDP data were compiled from the National Accounts Statistics. The open economy provides exposure to more advanced technology and enables a competitive business environment for the firms. To capture this, we used import intensity as the ratio of imported inputs to total inputs at the sub-sector level. Finally, innovation and existing technology in the industry is the most crucial factor to account for technology intensity, and it is measured as the ratio of plant and machinery cost to total output at the sub-sector level. To understand the firm-level determinants that influence the resource use efficiency, the study used financial structure, accessibility to quality raw material, practising quality standards, the scale of operation[1] (firm-size) and firms-age as predictor variables and TTE and PTE as the outcome variable. To know the role of financial structure, profit rate and quick ratio were calculated. ASI classifies total inputs (materials) broadly as indigenous and imported/improved. We used this information to measure firms' accessibility to better and quality raw material obtained by the ratio of improved raw material to total raw material. ASI also provides information about firms having International Organization for Standardization (ISO) certification, we incorporate this information as a dummy variable. Other control variables such as firm size and firm age are used as dummy variables.

Semi-parametric four-stage DEA

Our empirical strategy is built on both parametric and non-parametric methods. DEA is one of the most frequently used analytical tools for efficiency analysis. The traditional DEA is criticized for not considering intermediate output, hence the biased efficiency scores. Recently, Zeng et al. (2018) proposed a semi-parametric four-stage DEA framework that combines DEA and SFA methods. It allows to analyse resource use efficiency more accurately by considering the effect of statistical noise, also to identify macro-level and firm-specific variables that explain efficiency differences.

In the first stage, following Banker et al. (1984), the basic model of DEA is applied using output-oriented variable returns to scale (Eq.1) to get the initial estimates of the efficiency of each Decision-Making Unit (DMU). In this study, DMU refers to a firm in the food industry.

[1]Based on the new definition of MSMEs firms were classified as micro if the turnover is not more than Rs. 5 Crore, small between Rs. 5 to 50 Crore, medium between Rs. 50 to 250 Crore and large if the turnover is more than Rs. 250 crore

$$Max\ \pi + \mathcal{E}\left[\sum_{i=1}^{n} V_i^- + \sum_{r=1}^{m} V_r^+\right],$$

Subject to,

$$\sum_{j=1}^{k} \lambda_j X_{ij} + V_i^- = x_{ijo} \qquad i = 1,2,\dots,n;$$

$$\sum_{j=1}^{k} \lambda_j y_{rj} - V_r^+ = \pi y_{rjo} \qquad r = 1,2,\dots,m;$$

$$\sum_{j=1}^{k} \lambda_j = 1$$

$$\lambda_j \geq 0 \qquad j = 1,2,\dots,k. \qquad \text{...(1)}$$

Where, $\lambda_1, \lambda_2, \dots, \lambda_n$ and π are decision variables, x_{ijo} and y_{rjo} represent the i^th^ input and the r^th^ output of the j^th^ DMU, respectively. V_i^- refers to input slack, i.e, the same level of output without further reduction in input use, and V_r^+ is output slack that indicates a further rise in output at the same level of input. The optimal solution for Eq.(1) gives the initial performance measures for each firm. The firm is said to be on the frontier if the estimates, $V_i^{-*} = V_r^{+*} = 0$ and $\pi^* = 1$, otherwise ($\pi^* < 1$) the actual output for a firm has the scope to increase to π^*. Further, pure technical efficiency (PTE) and total technical efficiency (TTE) can be obtained from the envelope set of Eq.(1) assuming constant returns to scale and variable returns to scale respectively. This allows us to get scale efficiency (SE) as the ratio of TTE to PTE. For performing DEA, the presence isotonicity (output does not decrease with increased input) between input and output is confirmed by the Kendall tau rank method of correlation. In the second stage, the estimates of input and output slack obtained from stage 1 are used in the SFA, independently developed by Aigner et al. (1977) and Meeusen and van den Broeck (1977). It specifies a functional form comprising the vector of macro variables (m_{xit}) and composite error – random error (v_{xit}) and inefficiency (u_{xit}) as in Eq. (3).

$$V_i^- = x_{io} - \sum_{j=1}^{k} \lambda_j X_{ij} \qquad i = 1,2,\dots,n;$$

$$V_r^+ = \sum_{j=1}^{k} \lambda_j y_{rj} - \pi^* y_{ro} \qquad r = 1,2,\dots,m;$$

$$\text{...(2)}$$

$$V_{xit} = \beta m_{xit} + v_{xit} + u_{xit},$$

$$\mathrm{x} = 1,\dots,\mathrm{X}, \mathrm{i} = 1,\dots,\mathrm{I} \qquad \text{...(3)}$$

Where, V_{xit} is a slack variable of x^{th} input of i^{tt} DMU/firm, and composite error (v_{xit}, u_{xit}) are assumed to be distributed independently of each other and of m_{xit}. $v_{xit} \sim N(0, \sigma_{vx}^2)$ reflects the effect of statistical noise and $u_{xit} \geq 0$ ($u_{xi} \sim N^+(\mu^x, \sigma_{ux}^2)$) captures managerial inefficiency. β, μ^x, σ_{vx}^2, σ_{ux}^2 are the parameters to be estimated for each input slack. We used a time-varying decay model (Battese and Coelli 1992) for SF model, and the composite error term is decomposed following Jondrow et al. (1982). To reduce the effect of macro variables and account for statistical noise, the following adjustment formula is used.

$$x_{ni}^A = x_{ni} + [max_i\{m_i\hat{\beta}^n\} - m_i\hat{\beta}^n] +$$

$$[max_i\{\hat{v}_{ni}\} - \hat{v}_{ni}], \mathrm{n} = 1,2\dots,\mathrm{N};$$

$$\mathrm{i} = 1,2,\dots,\mathrm{I} \qquad \text{...(4)}$$

Where, x_{ni} and x_{ni}^A represent the observed and adjusted input values respectively and $[max_i\{m_i\hat{\beta}^n\} - m_i\hat{\beta}^n\}$ brings all DMUs that operate in the same favourable environment together and the ones that can not be captured by $[max_i\{\hat{v}_{ni}\} - \hat{v}_{ni}]$. By using the adjusted inputs from Eq.(4), we repeat the DEA to get improved efficiency estimates. To identify the firm-specific determinants that affect resource use efficiency we use Truncated regression Eq.(5). Since the efficiency measure is bounded between 0 and 1, several studies have used Tobit model (Merkert and Hensher, 2011; Selim and Bursalioglu, 2013). Simar and Wilson (2007), however, suggests using Truncated regression as it gives more accurate estimates.

$$E_{li} = \beta_0 + \beta_i X_{lt} + \varepsilon_{lt} \quad \ldots(5)$$

Where, E_{li} is efficiency, X_{lt} is a set of firm-level variables, and β_s and ε are parameters to be estimated.

Results and discussion

The incremental use of inputs may increase the output, but may or may not accelerate productivity growth. As a border indicator, factor intensity of the FPI and its sub-sectors at the industry level was estimated for major inputs, *viz.* labour, capital, material and fuel. It is evident from Figure 1 that from 1980-81 to 2017-18, the capital used to produce a unit of GVA has significantly increased over time, from Rs. 1.0 million to Rs. 2.10 million. The material intensity and fuel use pattern almost remained unchanged but with a fluctuating trend. Among the sub-sectors, a similar pattern of factor intensity is observed (Appendix A), except for meat, fish and fruits and vegetables where capital use intensity declined in the recent period. This prompted us to explore the possible avenues of improvement in the efficiency of factors, particularly capital.

The descriptive statistics of the variables considered in the four-stage-DEA model with firm-level balanced panel data shows the average GVA of the firms at Rs. 1670 billion (Table 1). The average fixed capital investment was Rs. 549 billion and a significant amount of it was spent on the construction of buildings (Rs. 115 billion) and purchase of plant and machinery (Rs. 73.6 billion). Workers were employed around 86,823 man-days per annum, varies from 1,333 to 4,58,943 man-days across firms (Table 1).

With rising diversification and value addition, the Indian food processing sector has the potential to increase its output at the given level of inputs. Accordingly, the output-oriented DEA model was used to understand the food processing firms' potential to increase their production, if the given inputs are utilized efficiently. Also, it is vital to understand whether the firms have any slack in output and inputs to identify the source of efficiency. To check this, summary statistics of output and inputs slacks were examined. From Table 2 one could make out that the mean value of output slack is 0, which indicates that there is no further scope for exploring their inefficiency. On the other hand, there is a considerable slack of 0.45 in fixed capital, 0.40 in building, 0.56 in plant and machinery, and 0.12 in man-days indicating the presence of resource use inefficiency in the input use.

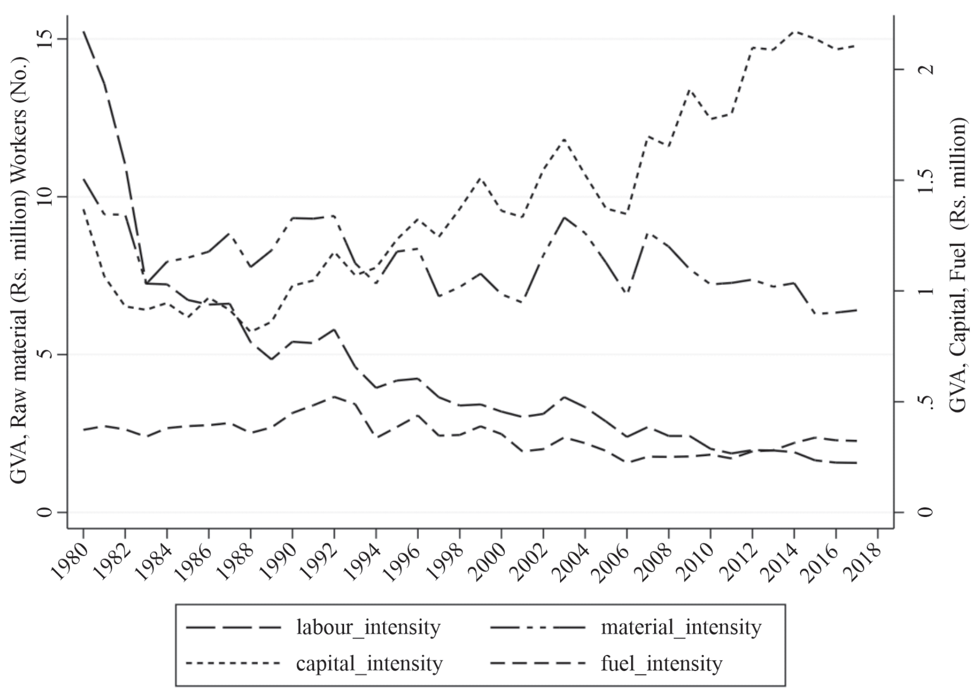

Figure 1 Pattern of factor intensity in food processing industry
Source ASI, MOSPI, GoI.

Table 1 Summary statistics of the firms

Variables	Obs.	Mean	SD.	Min.	Max.
GVA	805	1,670.00	2,070.0	9.2	19,000.0
Fixed capital	805	549.00	789.0	0.4	3,940.0
Plant &Machinery	805	73.60	190.0	0.0	2,650.0
Building	805	115.00	156.0	0.3	1,280.0
Man-days (workers)	805	86,823	67,774	1,133	4,58,943
		Macro-level variables			
SDP	805	6.36	2.71	-15.38	27.08
Import intensity	805	0.30	1.00	0	13.21
Technology intensity	805	0.18	0.06	0	0.57
		Firm-specific variables			
Quick ratio	805	9.20	1.19	4.97	7.45
Profit rate	805	-1.75	65.33	-12.57	55.90
Import of material	613	2.43	33.22	0	73.37
ISO certification	805	1.81	0.38	0	1
Firm-size	805	1.69	0.46	0	1
Firm-age	805	3.55	1.45	0	6

Note GVA, fixed capital, plant & machinery and building cost are in Rs. Billion and SDP. Import intensity, Technology intensity, Quick ratio, Profit rate and Import of material are in %.
Source Author's estimates

Table 2 Summary statistics of output and input slacks

Particulars	Obs.	Mean	SD.	Min.	Max.
		Model I			
Output slack	805	0.00	0.00	0.00	0.00
Fixed capital slack	805	0.45	1.02	0.00	7.69
Man-days slack	805	0.08	0.31	0.00	2.83
		Model II			
Output slack	805	0.00	0.00	0.00	0.00
Building slack	805	0.40	1.08	0.00	11.05
Plant & Machinery slack	805	0.56	1.10	0.00	7.07
Man-days slack	805	0.12	0.35	0.00	3.16

Source Author's estimates

The efficiency scores obtained for FPI and sub-sectors in model I, in columns (2), (4) and (6) of Table 3 indicate the efficiency scores of DEA (first step of four-stage DEA), and column (3), (5) and (7) show the resource use efficiency estimates accounting for the macro environment and statistical noise (third step of four-stage DEA). We also performed the Wilcoxon matched-pairs signed-ranks test to scrutinize the equality of matched pairs of DEA efficiency measures from the first and third stage DEA. The value of the Wilcoxon signed-rank for Total Technical Efficiency (TTE), Pure Technical Efficiency (PTE) and Scale Efficiency (SE) is significant at 1%, confirming the differences in the outcomes of the first and third stage DEA, and the macro environment has considerable influence on the resource use efficiency. The overall efficiency score of FPI during 2013-2018 was 11% the TTE, 26% in PTE and 45% in SE. Although there is a difference in the PTE and SE, a similar difference in TTE (around 10%) is observed in models I and II. Among the sub-sectors, a similar pattern of resource use efficiency is found, except for oils and fats. Among

Table 3 Resource use efficiency measures of food processing industry and sub-sectors

Particulars (1)	Total Technical Efficiency (2)	Total Technical Efficiency[a] (3)	Pure Technical Efficiency (4)	Pure Technical Efficiency[a] (5)	Scale Efficiency (6)	Scale Efficiency[a] (7)	Total Technical Efficiency (8)	Total Technical Efficiency[a] (9)	Pure Technical Efficiency (10)	Pure Technical Efficiency[a] (11)	Scale Efficiency (12)	Scale Efficiency[a] (13)
	Model I						Model II					
Meat products	0.04	0.01	0.05	0.05	0.86	0.29	0.05	0.01	0.05	0.05	0.95	0.26
Fish products	0.25	0.08	0.28	0.28	0.92	0.25	0.27	0.08	0.29	0.29	0.9	0.23
Processed Fruits & Veg.	0.11	0.02	0.13	0.13	0.89	0.2	0.13	0.02	0.14	0.14	0.92	0.18
Oils & fats	0.45	0.24	0.53	0.54	0.85	0.37	0.58	0.24	0.63	0.63	0.93	0.34
Dairy products	0.28	0.13	0.35	0.35	0.81	0.36	0.35	0.13	0.4	0.4	0.88	0.3
Grain & starch products	0.15	0.08	0.25	0.25	0.73	0.44	0.16	0.08	0.27	0.27	0.72	0.39
Bakery products	0.07	0.02	0.14	0.14	0.76	0.27	0.12	0.02	0.19	0.19	0.78	0.22
Sugar	0.13	0.14	0.2	0.21	0.65	0.65	0.16	0.14	0.23	0.23	0.72	0.59
Sugar confectionery	0.21	0.16	0.3	0.3	0.78	0.47	0.24	0.15	0.3	0.3	0.84	0.46
Miscellaneous foods	0.27	0.1	0.32	0.32	0.84	0.31	0.3	0.1	0.36	0.36	0.83	0.27
Animal feed	0.55	0.09	0.57	0.57	0.92	0.16	0.23	0.11	0.29	0.29	0.79	0.4
FPI	0.19	0.11	0.26	0.26	0.75	0.45	0.58	0.09	0.62	0.61	0.9	0.14
Wilcoxon signed-rank test	13.90***		-4.04***		16.96***		17.24***		-6.99***		20.17***	

Note Total Technical Efficiency[a], Pure Technical Efficiency[a], Scale Efficiency[a] refers to efficiency measures after accounting for macro variables
*** indicates significance at 1% level
Technical efficiency of 0.00 (0%) and 1.00 (100%) indicates low and high level of efficiency
Source Author's estimates

these groups, the grain and sugar industries showed a comparatively higher level of scale efficiency. Being a traditional sector and a continuous increase in food grain and sugar products might have added gradual improvement in the scale and resource use efficiency.

The pattern of resource use efficiency for some of the important industry characteristics is presented in Table 4. It is clear that in both the models there is not much difference in the efficiency measure in rural and urban areas. In the urban areas, 12% of TTE, 30% of PTE and 40% of SE were recorded. The corresponding figures for the rural area are 11, 20, and 40%. It is not appropriate to compare the efficiency measures across the periods as these are obtained by comparing the frontier in different points of time. However, in our sample the firms were constant in different times, it can be concluded that, on average, the firms in the industry were moving far or towards the frontier over the period. The findings show that the resource use efficiency increased marginally, from 10% in 2014 to 12% in 2018 in model I, and it increased to 13% in 2018 from 10% in 2014 in model II. There exists a variation in the efficiency pattern across the scale of operation. It is clear from model I that the larger firms are relatively better at managing resources. However, the results in model II showed that the small and medium firms' TTE is on par with that of large firms. Although there is no clear-cut relationship between firm size and efficiency, qualitatively there is an indication that by increasing the scale of operation, efficiency in the use of resources can be enhanced. Compared with large firms, small and medium firms face more

Table 4 Efficiency measures across industry characteristics

Indicators	Model I			Model II		
	Total Technical Efficiency[a]	Pure Technical Efficiency [a]	Scale Efficiency[a]	Total Technical Efficiency[a]	Pure Technical Efficiency [a]	Scale Efficiency[a]
		Sector				
Rural	0.11	0.23	0.47	0.11	0.25	0.43
Urban	0.12	0.32	0.41	0.12	0.38	0.35
		Year				
2014	0.10	0.26	0.41	0.10	0.31	0.36
2015	0.12	0.29	0.42	0.12	0.32	0.37
2016	0.11	0.23	0.49	0.11	0.27	0.44
2017	0.11	0.24	0.49	0.11	0.26	0.47
2018	0.12	0.27	0.44	0.13	0.32	0.39
		Scale of operation				
Micro	0.05	0.49	0.16	0.06	0.25	0.26
Small	0.04	0.31	0.15	0.11	0.32	0.38
Medium	0.06	0.28	0.27	0.11	0.28	0.40
Large	0.14	0.24	0.56	0.12	0.29	0.41
		Organization type				
Partnership	0.01	0.08	0.08	0.01	0.09	0.08
Limited liability partnership	0.06	0.49	0.24	0.06	0.50	0.23
Government company (public)	0.05	0.12	0.44	0.05	0.13	0.41
Government company (private)	0.17	0.65	0.25	0.17	0.70	0.22
Non-Government Company (public)	0.09	0.26	0.36	0.09	0.31	0.31
Non-Government Company (private)	0.13	0.27	0.53	0.14	0.29	0.51
Co-operative Society	0.14	0.22	0.61	0.14	0.26	0.53

Note Total Technical Efficiency [a] , Pure Technical Efficiency [a] , Scale Efficiency [a] refers to efficiency measures after accounting for macro variables. Technical efficiency of 0.00 (0%) and 1.00 (100%) indicates low and high level of efficiency
Source Author's estimates

Table 5 Macro-level correlates of resource use efficiency in food processing industry

Particulars	Model I		Model II		
	Input slacks				
	Fixed assets	Workers man-days	Cost of building	Plant and machinery cost	Workers man-days
SDP	-0.064**	-0.015	-0.037**	-0.035**	-0.045
	(0.032)	(0.025)	(0.028)	(0.030)	(0.032
Import intensity	-0.141**	-0.110*	-0.047**	-0.089**	-0.072*
	(0.085)	(0.066)	(0.075)	(0.079)	(0.085)
Technology intensity	-0.801***	-0.742***	-0.783**	-0.832***	-0.472***
	(0.205)	(0.312)	(0.180)	(0.203)	(0.166)
Control for year effect	-0.084	-0.128	-0.046	-0.006	0.051
	(0.068)	(0.054)	(0.029)	(0.005)	(0.002)
Control for firm effect	0.059	0.078	0.049	0.061	0.098
	(0.013)	(0.012)	(0.021)	(0.025)	(0.045)
Constant	16.720	25.714	9.133	0.964	-10.288
	(13.671)	(10.928)	(7.818)	(13.084)	(14.408)
Log likelihood	152.47	143.63	62.31	12.70	09.93
LR test	117.80***	9.27***	42.96***	178.78***	357.75***
gamma	0.99	0.99	0.99	0.99	0.99
No. of obs.	805	805	805	805	805
No. of firms	161	161	161	161	161

Note Standard errors in parentheses; The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively. *Source* Author's estimates

challenges in accessing finance (Ali 2016, Singh and Vyasulu 1990). The difference in the constraints in accessing credit and reducing the market imperfections help the firm to move towards an optimal scale of operations that brings more efficiency in resource use. Across the type of organization[2], the co-operative societies and private industry groups utilize resources more efficiently. The public companies having a maximum number of government shareholders and firms working in partnership mode have considerably less efficiency scores.

There are some major correlates of resource use efficiency. The factors were identified at the macro level and the firm level, so as, to help policymakers, investors and managers to take an appropriate decision. The effect of the macro environment on resource use efficiency in the food industry was analysed by regressing each input slacks against macro variables - SDP, import intensity and technology intensity, under the stochastic frontier framework. Before choosing SFA it is necessary to check the appropriateness of its use. To confirm this, parameter gamma is calculated which indicates the proportion of technical inefficiency in the total square variance. It is clear from Table 5 that the estimated gamma value is closer to one in all the input slack regression, indicating the presence of significant variation in technical inefficiencies. Again a significant value of Likelihood Ratio (LR) rejects the null

[2]Partnership – persons agreed to share the profit of a business carried by all or any one of them; Limited Liability Partnership (LLP) – firms incorporated under LLP Act 2008 has unique ROC; Government company (Public) – company paid-up capital by the Government (Central/State/Local) is not less than 51 % with at least seven number of stakeholders; Government company (Private) – company paid-up capital by the Government (Central/State/Local) is not less than 51 % with at least one number of stakeholders; Non-Government company (Public) – company paid-up capital by the Government (Central/State/Local) is less than 51 % with at least seven number of stakeholders; Non-Government company (Private) – company paid-up capital by the Government (Central/State/Local) is less than 51 % with at least one number of stakeholders; Co-operative society – Society formed through co-operation and funds are raised by the member's contributions

hypothesis of OLS regression. From this preliminary analysis, the study confirms that the SFA is more appropriate to analyse the impact of macro-level variables on resource use efficiency. The negative sign of the coefficient of all the macro variables for each input slack indicates the appropriateness of the selected variables. The negative and significant coefficient of SDP indicates that the regional policy and business environment across the states have positive implications in reducing the negative consequences caused by inefficient resource use in FPI. As the regional economy grows, opportunities for investment in infrastructure and developmental activities will rise, which shall further facilitate better resource flow and management. The effect is more important particularly in the long run, which is indicated by the significant coefficient for the fixed cost (-0.064), building (-0.037), and plant and machinery investment (-0.035).

The more open the economy, the larger will be the opportunity to access better knowledge and technology, and thus, it improves competitiveness. Besides, it may open up the opportunity to improve operational and managerial skills that further helps in better resource management. Liberalization of the Indian economy opened up the opportunity to exchange knowledge and technology. However, for the food sector, it was only after several years, the importance of foreign technology was considered as a critical input. Many studies acknowledge the role of imported goods in raising the productivity of Indian manufacturing units (Caselli 2017, Chand and Sen 2002, Milner et al. 2007; Topalova and Khandelwal 2011). The study used the import intensity of each sub-sector as a measure of openness at the industry level as a macro indicator. In line with the expectation, the negative and significant coefficient of import intensity indicates that more openness reduces input slacks and improves resource use efficiency. The existing level of technology in the industry is one of the key components that bring more productivity in the industry by improving the efficiency of other factors of production, such as labour, managerial skill, and use of other long-term investments. The analysis included technology intensity defined as the ratio of plant and machinery cost to total output at the industry level, to analyse the effect of technology uses on resource use efficiency. The strong empirical evidence (at 1% significance level) of technology intensity across all the input slack supports our explanation, to say that better use of technology will lead to improved factor utilization. Presently in the FPI, only 0.84% of the firms have R&D units, and therefore incentivising R&D investment by the domestic firms is indeed for the industry growth.

Table 6 presents firm-specific correlates of resource use efficiency obtained by the truncated regression model. Efficiency measures, TTE and PTE were regressed with firm-specific variables such as the quick ratio, profit rate, availability of better and quality raw material, quality standard, firm-age, and firm-size. The coefficient of quick ratio measured as the ratio of the difference in current assets and inventory to current liabilities is positive and significant for both TTE and PTE in the model I and model II, suggesting that managing working capital and sound financial health of the firms will have a positive impact on resource use efficiency. An increase in firms' quick ratio by one standard deviation will increase TTE and PTE each by seven percentage points in model I, and eight and seven percentage points increase in TTE and PTE, respectively in model II. The coefficient of the profit rate is positive and a similar pattern is also observed in models I and II for TTE and PTE. However, the results are weak to interpret that better profitability always leads to improved efficiency. It is also evident that accessibility and availability of quality raw materials in time is crucial for the firms to enhance their resource use efficiency as indicated by the positive and significant coefficient of quality raw materials on TTE and PTE in model I and model II. The coefficient of ISO certification is negative and significant, indicating that the firms with no ISO certification used resources less efficiently by 14 (TTE) and 21 (PTE) percentage points in model I and 9.3 (TTE) and 6.1 (PTE) percentage points in model II. On average, large firms are more efficient by 14 and 16 percentage points, respectively, in model I and model II as measured in terms of PTE. However, TTE results are not significant. Efficiency patterns across the firm-age indicated that very old firms are at the disadvantage stage as their efficiency score is very low compared with the newer firms, perhaps differences in the pace of technological advancement resulted in the differential impact on their resource use efficiency.

Table 6 Firm-specific determinants of resource use efficiency in food processing industry

Particulars	Model I		Model II	
	TTE	PTE	TTE	PTE
Quick ratio	0.061***	0.062***	0.067***	0.058***
	(0.031)	(0.024)	(0.046)	(0.016)
Profit rate	0.045	0.051	0.092	0.031
	(0.006)	(0.018)	(0.049)	(0.018)
Quality raw material	0.018**	0.015***	0.017***	0.015***
	(0.001)	(0.007)	(0.011)	(0.009)
ISO certification	-0.146***	-0.213***	-0.093*	-0.061*
(base = firm with ISO certification)	(0.085)	(0.002)	(0.009)	(0.024)
Firm size	0.073	-0.1436**	0.010	-0.160***
(base = large firms)	(0.048)	(0.022)	(0.009)	(0.024)
Firm age	-0.119	0.032	-0.073	0.028
(base = > 40 years)	(0.013)	(0.035)	(0.014)	(0.028)
31-40 years	-0.078	0.097**	-0.007	0.089*
	(0.023)	(0.033)	(0.036)	(0.089)
21-30 years	0.023**	0.0581***	0.022*	0.158***
	(0.012)	(0.033)	(0.013)	(0.157)
11-20 years	0.045***	0.165***	0.045***	0.143***
	(0.013)	(0.035)	(0.014)	(0.141)
< 10 years	0.112	0.181**	0.115	0.023**
	(0.051)	(0.040)	(0.016)	(0.023)
Control for year effect	0.015	0.036	0.047	0.066
	(0.003)	(0.013)	(0.026)	(0.062)
Control for firm effect	0.039	0.047	0.039	0.043
	(0.023)	(0.026)	(0.025)	(0.021)

Note Standard errors in parentheses; The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.
Source Author's estimates

Conclusions

The growth pattern of inputs and output of the industry should be accomplished by productivity growth. The economic theory largely agrees with the fact that the growth without productivity gain will not generate much gain to the national income, and thus will not ascertain in expanding the industry competitiveness in the long run. To attain better productivity role of technology and efficient use of resources are vital. This study of resource use efficiency and its associated factors of the Indian FPI indicated that the overall efficiency of FPI is very low (11%), and the source of inefficiency has largely been associated with the suboptimal use of capital. Thus, there is ample scope within the sector to maximize the productive capacity by enhancing the capital use efficiency, particularly in the form of technology operation and up-gradation. The regional policy support and pro-business environment enabling access to global technology along with incentives for innovations in the domestic firms have long-run implications, as they considerably reduce capital use inefficiency in the industry as a whole. Better liquidity rate and having timely accessibility of quality raw materials were found to have a significant influence on the resource use efficiency at the individual firm-level. A positive association of the scale of operation and efficiency parameters was also observed. Thus, ensuring working capital availability, particularly to the small firms and sinking market imperfections in getting resources greatly influence in reducing the level of resource use inefficiency. Since Indian agriculture is predominantly operated by smallholders, getting the desired amount of quality farm produce at one go is a great challenge. Consolidation of the perishables through co-operatives is although operating in the country, but is limited to a few commodities. Presently, at the country level policy is emphasizing farmer producers' organizations, and therefore this institution can be trained to channel quality raw material to the food processing sector. Thus, the farm-industry linkage would be a win-win situation for farmers as well as for the processers. A coherent approach of taking policy measures specific to the regional preference along with facilitating factors at the firm-level efficiency shall contribute to the overall development of the food processing industry.

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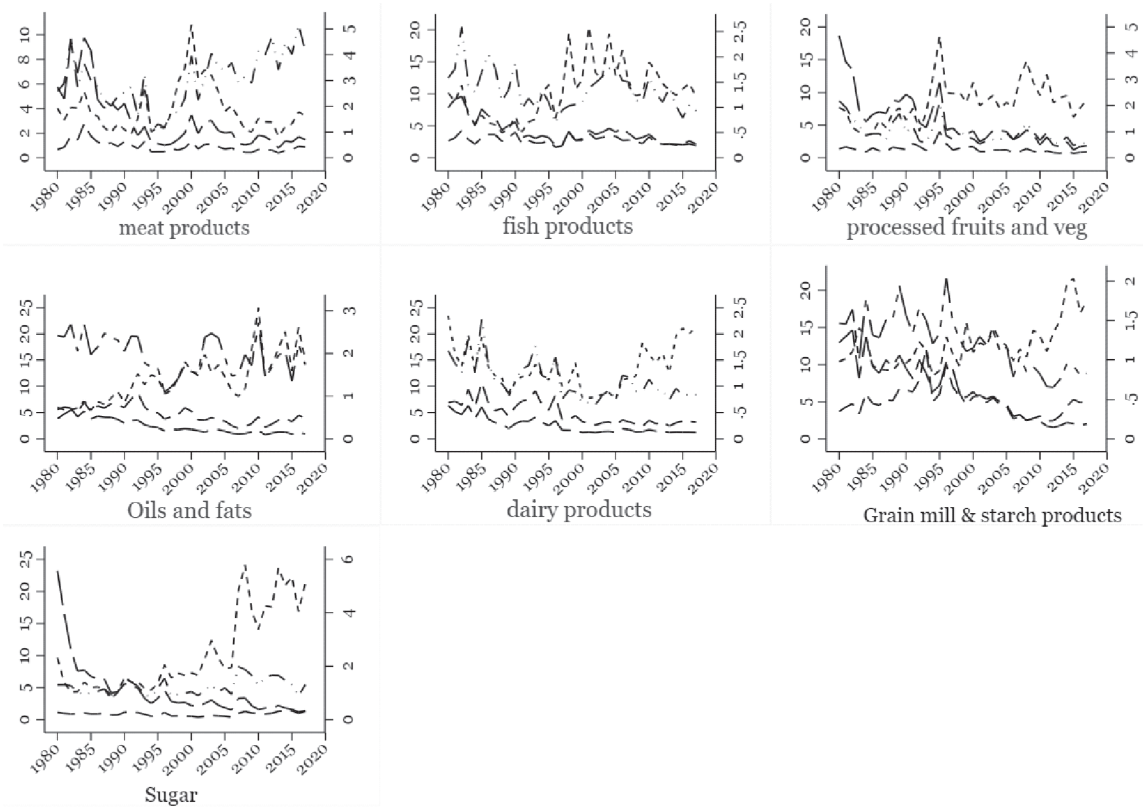
Appendix A Pattern of factor intensity across sub-sectors in FPI



Source: Author's calculations based on data from ASI

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The changing structure of agricultural marketing in India: a state-level analysis of e-NAM

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Abstract The government of India launched e-NAM to remove inefficiency and enhance transparency in the agricultural marketing system and ensure fair prices to farmers for their produce. This paper examines the (i) extent of APMC markets covered by e-NAM across the states, and stakeholders' participation in e-NAM; (b) pattern of trade, its concentration, and determinants; (c) benefits of e-NAM to farmers; and (d) constraints in e-NAM trading. The evidence shows no significant price advantage for most commodities across the states on the implementation of e-NAM. This indicates the need for strengthening quality assaying and accelerating the issuance of unified licenses to promote inter-market trading and achieve better price discovery.

Keywords Trade performance and concentration, stakeholder's participation, effect on farmers price, constraints in e-NAM trading

JEL Codes Q11, Q13, Q180

A series of policy measures taken by the Government of India has resulted in self-sufficiency in foodgrain production. However, an ineffective marketing system remains a cause of concern (Chand 2016). Hence, the Government of India launched an electronic-National Agriculture Market (e-NAM) — a pan-India online trading portal on 14 April 2016 — to improve price discovery in real-time by eliminating the information asymmetry between buyers and sellers. It connects surplus production regions with deficit regions through an online platform, which may lead to better market competition, and thus better prices for farmers for their produce. It also provides an option for buyers to access products across markets.

Nonetheless, our understanding of the effects of e-NAM on farmers' prices is limited. Kumar et al. (2020) find no price advantage in e-NAM over Agmarknet markets. Bachaspati and Pathak (2018) even reported a decline in the prices after the introduction of e-NAM in Chattisgarh. Reddy and Mehjabeen (2019) and Bhattacharya and Chowdhury (2020) noted a positive effect of e-NAM on commodity prices. Kumar and Pant (2020) and Rao et al. (2020) have reported that e-NAM has helped better price realization. On the other hand, Sekhar and Bhatt (2018), Reddy (2018) and Levi et al. (2020) provide mixed evidence of e-NAM. The evidence in most of these studies is either based on a few commodities from a small number of states and the inference cannot be generalized. There is an information gap on a holistic view of e-NAM in terms of size of the trade, its pattern and price effects. Against this backdrop, this paper examines the following questions: (i) to what extent APMC markets are connected with e-NAM across? (ii) what is the pattern of trade, concentration, and its determinants? (iii) whether e-NAM has benefitted farmers? and (d) what are the constraints in e-NAM trading?

Data and method

We utilize both secondary and primary data. The secondary data on daily e-NAM transactions (i.e, minimum, modal and maximum prices, and quantity traded) were collected from the e-NAM portal (https://enam.gov.in) for July 2019 to June 2021, yielding a total of 6.4 lakh observations. State-level data on regulated markets, cultivators, gross cropped area, crop production, gross value added in the agriculture, and monthly commodity prices published by different government agencies were compiled. To study the perceptions of stakeholders about e-NAM and operational constraints, twelve focused group (FGD) discussions involving farmers, traders, and mandi officials were conducted at the APMCs of Chennai, Dindigul, Vellore, and Madurai districts of Tamil Nadu during February - March 2020.

We use Herfindahl-Hirschman Index (HHI) to measure the crop-group-wise concentration of e-NAM trade across states to capture the relative size of dominance by each state. The HHI is calculated as the squared sum of all the states' percentage share of trade (OECD 2018). It ranges between 0 and 10,000. A value of HHI less than 1500 indicates less concentration, 1500 to 2500 moderate concentration, and more than 2500 high concentration (Kranenburg 2017, Willingham and Green 2019).

We consider the value of trade as the performance of the state in e-NAM. The trade value of each state was normalized by dividing trade value by their respective state agricultural gross value added (AgGVA) to nullify the scale effect. It is hypothesized that if more markets are linked with e-NAM, more are the transactions in e-NAM. It is assumed that the proportion of farmers and traders' participation in e-NAM would expand the trade. The unified license (UL) for the traders— a pre-requisite for inter-market transactions — is an important factor influencing the volume of trade. It is expected that incentives such as cash awards for best-performing farmers, traders and e-markets would enhance e-NAM trade. It is plausible that the nature of commodities traded such as food grains and cash crops vastly determine the value of trade. With this background, an empirical panel regression model was fitted to analyze the determinants of e-NAM trade. A panel of 15 states was constructed and the fixed effect model was estimated:

$$Y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + \beta_6 D_{1it} + \beta_7 D_{2it} + \varepsilon_{it}$$

where Y is the dependent variable, Xs and Ds are explanatory variables, βs are parameters, ε is an error term with zero mean and constant variance. Y is defined as the proportion of e-NAM trade value in total state AgGVA of i^{th} state in t^{th} year. X_1 is the percentage share of e-markets in the total regulated markets. X_2 is farmers' participation (%), which is measured as the proportion of registered farmers in e-NAM total cultivators in a state. X_3 is the trader's concentration (total number of traders per unit of gross cropped area (GCA)). X_4 is the proportion of traders who received the unified license. X4 is the share of non-food commodities trade value in the total trade. The policy dummy, D_1 is defined as the states which have given some form of monetary incentives as one and otherwise zero. D_2, a year dummy, was introduced to control time-invariant unobserved individual characteristics that can be correlated with observed variables.

The linking of agricultural markets across the country is expected to affect the farmers' price realization in many ways. For instance, e-tendering would result in more transparency, and even intra-market transactions would reduce the cartelization of traders. Also, e-trading by increasing the number of buyers is expected to enhance competitiveness. For this purpose, we used commodity-wise daily modal prices to derive monthly prices and aggregated monthly prices at the state level. We consider Agmarknet prices for comparing with e-NAM prices. Agmarknet covers more than 350 commodities across 3200 markets. It may be noted that Agmarknet covers e-NAM as well as non-e-NAM markets. The non-availability of data on exclusive non-eNAM market prices at the state level deprives the accuracy of our estimates on the price difference. However, the direction of bias could be identified. For instance, the negative (positive) price difference of e-NAM over non-e-NAM markets indicates an underestimation (overestimation) of the difference. Shapiro-Wilk normality test of price series indicated a violation of the normal distribution. Hence, we applied a non-parametric test (also called a distribution-free test). As we are interested in the paired monthly price differences, we choose Wilcoxon signed-rank test, a non-parametric test equivalent to the parametric paired t-test (Siegel and Castellan 1988).

Results and discussion

Pattern and growth in key characteristics of e-NAM

Linking all the markets with e-NAM and active participation of stakeholders in e-NAM trading are the important factors in the success of e-NAM (Table 1). The performance on this count indicates substantial growth in the registration of Farmer Producer Organizations (FPOs) (144%) and the issuance of unified licenses (UL) (121%) in the past two years. A reasonable increase in linking of markets (71%) and traders' registration (40%) was also observed. However, the increase in farmers' participation, was very low (3%). Uttar Pradesh, Madhya Pradesh, Haryana and Telangana recorded a more than 60% increase in farmers' registration. Rajasthan recorded a good share in the markets, trader's registration, and issuance of UL. Active participation of FPOs was found in Maharashtra.

At the all-India level, only about 9% of the APMC markets were linked with e-NAM in July 2019 but their coverage is increased to 15% in June 2021 (Figure 1). The high coverage states (Himachal Pradesh, Rajasthan, and Gujarat) also could cover only about 30% of the total APMC markets. It implies that a majority of the markets are functioning in offline mode. From the FGD we find that those who are not comfortable with digitalization prefer to go for offline mode, and e-NAM is the last resort for them. Hence, expediting the mandi linking is essential to ensure greater participation of stakeholders in e-NAM. Farmers' e-NAM participation rate is the highest in Haryana (90%) and followed by Telangana (58%) as against the national average of about 13%.

Overall, about 86 traders per lakh hectare of GCA have registered for e-NAM at the all-India level. Uttarakhand has the highest intensity of the number of registered traders. In most other states it is less than 100. Unified

Table 1 State-wise e-NAM profile (as of June 2021)

States	Mandis		Farmers (in lakhs)		Traders		Unified licenses		FPOs	
	No.	%	No.	%	No.	%	No.	%	No.	%
Uttar Pradesh	125	12.5	33	19.3	34,758	20.1	110	0.2	223	11.9
Madhya Pradesh	80	8	30	17.7	21,555	12.5	393	0.7	80	4.3
Haryana	81	8.1	27	15.9	12,482	7.2	28	0	230	12.3
Telangana	57	5.7	18	10.7	5,709	3.3	5,709	9.7	55	2.9
Andhra Pradesh	33	3.3	14	8.4	3,365	2	3,365	5.7	170	9.1
Rajasthan	144	14.4	14	8.4	37,348	21.6	37,348	63.7	160	8.5
Maharashtra	118	11.8	12	7.1	20,073	11.6	0	0	257	13.7
Gujarat	122	12.2	9	5.1	9,325	5.4	105	0.2	86	4.6
Tamil Nadu	63	6.3	3	1.7	3,621	2.1	327	0.6	106	5.6
Jharkhand	19	1.9	2	1.3	2,064	1.2	39	0.1	75	4
Punjab	37	3.7	2	1.3	2,346	1.4	1	0	6	0.3
Odisha	41	4.1	2	1.2	5,848	3.4	5,848	10	159	8.5
Chhattisgarh	14	1.4	1	0.8	3,099	1.8	34	0.1	22	1.2
Himachal Pradesh	19	1.9	1	0.7	1,968	1.1	0	0	50	2.7
Uttrakhand	16	1.6	1	0.3	4,691	2.7	4,691	8	43	2.3
West Bengal	18	1.8	0	0.2	3,191	1.8	7	0	150	8
Puducherry	2	0.2	0	0.1	160	0.1	0	0	2	0.1
Chandigarh	1	0.1	0	0	80	0	0	0	0	0
Jammu & Kashmir	2	0.2	0	0	56	0	0	0		0
Karnataka	2	0.2	0	0	597	0.3	597	1	0	0
Kerala	6	0.6	0	0	217	0.1	35	0.1	3	0.2
All India	1,000	100	171	100	1,72,553	100	58,637	100	1,877	100
Growth* (%)	70.9		3.3		39.8		121.3			144.4

Source Compiled from the e-NAM portal
Note *indicates change over from July 2019 to June 2021

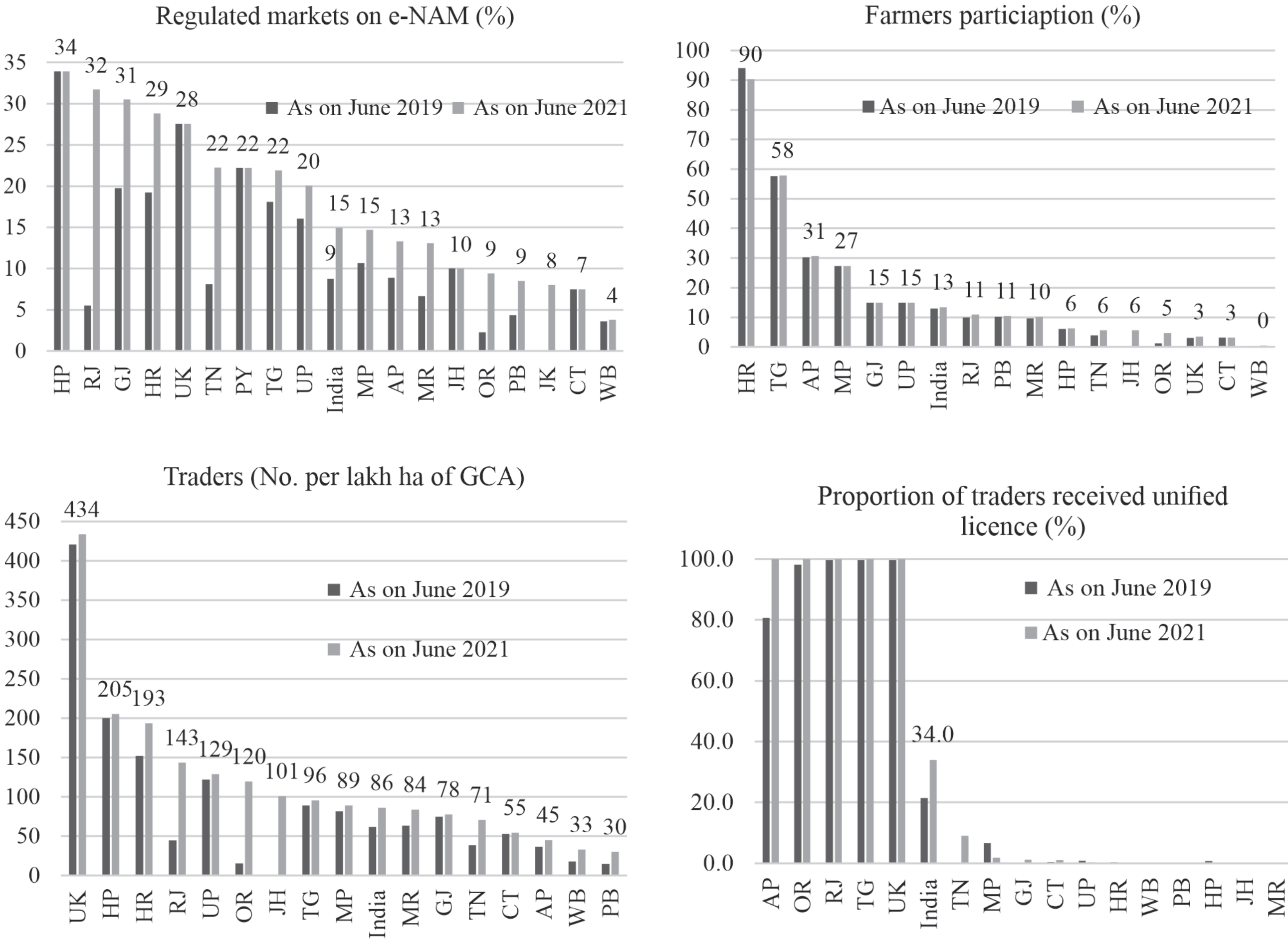

Figure 1 Regulated markets coverage and stakeholders' participation in e-NAM
Source Same as in Table 1

licenses essential inter-market trading is issued to only one-third of the traders. Also, high disparities were found in the issuance of UL among states. Five states issued UL to all traders, while in other states its issuance rate is very low or negligible.

Trade pattern and concentration in e-NAM

More than 175 commodities with a trading volume of 8.69 million tons in 2019-20 were traded through e-NAM, which is much smaller compared to their production (Tables 2 and 3). And , the year-on-year growth in 2020-21 was also very low (3.6%). Trade in cereals registered a decline of 19%, while the volume of pulses trade remained almost unchanged. The e-NAM trade in oilseeds, fruits, and vegetables is very low. Farmers expressed their concern about the uncertainty of sales in online trade and the spoilage of products if unsold. Vegetables and fruits consolidated their share in total trade. The HHI indicates that trade in pulses and oilseeds is highly concentrated in a few states. However, we find an upward trend in the concentration of four crop groups in 2020-21. The trade concentration in pulses and vegetables declined, which indicates the increasing participation of states in e-NAM.

The trade value increased by 14% between 2019-20 to 2020-2021. Although the cereals have the largest volume share the other commodity groups (comprising spices and dry fruits) have a larger value share The trade value of oilseeds more than doubled and it increased 1.7 times in the case of fruits. Cereals share rather declined about 11 percentage points, while that of oilseeds it increased to the same extent. Fruits and vegetables share also increased marginally. Overall, the trade concentration was moderate or high in all the commodities, except vegetables.

Table 2 State-wise and crop-wise trade concentration (Volume basis) in e-NAM

States	Cereals	Pulses	Oilseeds	Vegetables	Fruits	Others	All
			2019-20				
Total (million t)	4.69	0.93	0.36	0.88	0.11	1.72	8.69
Share (%)	54.0	10.7	4.2	10.1	1.3	19.8	100.0
			Share in total trade (%)				
Haryana	36.49	0.61	2.38	7.59	5.57	45.09	29.61
Rajasthan	5.02	11.35	45.01	0.07	0.01	5.03	6.80
Andhra Pradesh	0.05	0.38	18.37	35.86	28.58	25.42	9.84
Maharashtra	2.57	27.89	0.06	8.07	19.12	0.58	5.56
Punjab	9.85	0.08	0.08	14.91	9.73	11.32	9.19
Telangana	9.75	5.58	16.36	0.70	0.35	9.13	8.42
Madhya Pradesh	11.76	48.24	3.25	0.52	0.48	0.69	11.85
Uttar Pradesh	12.03	3.14	4.62	18.05	12.88	1.16	9.24
Odisha	8.42	0.11	2.21	0.00	0.00	0.16	4.68
Tamil Nadu	0.11	0.02	0.30	0.49	0.62	0.53	0.24
Himachal Pradesh	0.00	0.01	0.00	3.53	13.24	0.06	0.54
Others	3.95	2.57	7.36	10.22	9.41	0.83	4.03
HHI	1925	3282	2728	2075	1739	2919	1471
			2020-21				
Total (million t)	3.81	0.93	1.00	1.03	0.50	1.73	9.00
Share (%)	42.3	10.3	11.1	11.4	5.6	19.2	100.0
			Share in total trade (%)				
Haryana	48.54	1.68	19.39	7.85	2.13	37.07	31.03
Rajasthan	14.95	26.46	56.55	18.40	13.13	11.86	20.47
Andhra Pradesh	0.04	1.12	9.84	27.25	14.43	23.96	9.75
Maharashtra	3.64	31.09	0.27	8.25	56.04	0.65	8.96
Punjab	10.71	0.25	0.25	10.08	2.89	11.94	8.20
Telangana	5.67	7.85	9.33	1.23	1.47	9.82	6.36
Madhya Pradesh	5.08	23.23	0.75	0.81	0.07	0.24	4.77
Uttar Pradesh	3.80	1.39	0.74	10.84	0.87	0.61	3.24
Odisha	4.82	0.15	0.92	0.95	0.02	0.20	2.31
Tamil Nadu	0.17	0.03	0.03	6.70	1.41	3.06	1.51
Himachal Pradesh	0.00	0.01	0.00	2.37	5.84	0.07	0.61
Others	2.58	6.73	1.93	5.26	1.70	0.49	2.79
HHI	2810	2320	3763	1511	3576	2338	1714
Growth (%) *	-18.8	-0.5	178.0	17.5	338.4	0.8	3.6

Source Same as in Table 1; *Note* *indicates change over from July 2019 to June 2021

The progress of the e-NAM was assessed by comparing the trade with the total production and agriculture gross value added (AgGVA) (Table 4). The e-NAM trade accounts for 3% of the paddy and a half percent of wheat output, and about 2% of the total foodgrains production in 2019-20. Acuite (2021) also reported that about 5.84% of total foodgrains and oilseeds were traded through e-NAM in 2017-18. The figures are more or less the same for 2020-21. The value of trade also indicates a very low share (1.8%). Haryana (15%) and Rajasthan (7%) have a larger share. These findings indicate that although e-NAM commenced well, it

Table 3 State-wise and crop-group wise trade concentration (ad valorem basis) in e-NAM

States	Cereals	Pulses	Oilseeds	Vegetables	Fruits	Others	All
			2019-20				
Total (Rs Crores)	10,093	3,987	1,621	1,116	248	10,823	27,888
Share (%)	36.2	14.3	5.8	4.0	0.9	38.8	100.0
			Share in total trade (%)				
Haryana	45.5	0.6	2.1	9.9	10.1	36.1	31.2
Rajasthan	4.2	13.2	40.8	0.1	0.0	5.2	7.8
Andhra Pradesh	0.0	0.4	20.2	27.8	17.6	39.1	17.7
Maharashtra	7.6	6.1	18.4	0.9	0.6	7.5	7.7
Punjab	11.9	0.1	0.1	11.3	5.2	9.4	8.5
Telangana	2.1	26.9	0.1	14.0	19.7	0.5	5.5
Madhya Pradesh	10.3	46.5	2.8	1.5	0.6	0.5	10.8
Uttar Pradesh	9.9	3.1	4.7	15.1	7.8	0.5	5.2
Odisha	0.1	0.0	0.4	0.7	0.3	0.5	0.3
Tamil Nadu	5.4	0.2	4.0	0.0	0.0	0.1	2.3
Himachal Pradesh	0.0	0.0	0.0	7.4	30.4	0.1	0.6
Others	3.0	2.8	6.3	11.2	7.8	0.7	2.6
HHI	2531	3119	2507	1607	1874	3001	1660
			2019-20				
Total (Rs Crores)	8,073	4,785	5,402	1,423	669	11,557	31,909
Share (%)	25.3	15.0	16.9	4.5	2.1	36.2	100.0
			Share in total trade (%)				
Haryana	57.5	1.8	19.6	6.9	4.7	30.0	29.4
Rajasthan	11.2	28.4	56.2	20.2	32.3	12.1	22.5
Andhra Pradesh	0.0	1.2	9.2	24.6	22.2	34.5	15.8
Maharashtra	4.2	8.9	10.0	1.4	2.0	9.3	7.5
Punjab	12.1	0.3	0.3	7.7	2.0	10.1	7.2
Telangana	2.7	29.2	0.2	10.0	9.9	0.5	6.0
Madhya Pradesh	4.1	21.0	0.7	2.8	0.2	0.2	4.5
Uttar Pradesh	2.8	1.4	0.6	8.3	0.8	0.2	1.5
Odisha	0.1	0.0	0.1	7.2	1.4	2.7	1.4
Tamil Nadu	3.3	0.2	1.6	0.1	0.0	0.1	1.2
Himachal Pradesh	0.0	0.0	0.0	4.4	20.9	0.1	0.7
Others	1.9	7.6	1.5	6.5	3.5	0.3	2.4
HHI	3644	2246	3737	1412	2118	2427	1798
Growth (%)*	-20.0	20.0	233.3	27.5	169.5	6.8	14.4

Source Same as in Table 1
Note *indicates change over from July 2019 to June 2021

needs to go far away to realize its objectives.

The e-tendering or e-trading?

The e-tendering is a process involving online transactions between buyers and sellers within a market. While in the case of e-trading, the transactions are dispersed across buyers and sellers in different markets. Since the purpose of e-NAM is to connect the farmers and traders across markets through an online portal, we assess the share of inter-market trade in the total trade (Figure 2). Due to data accessibility constraints, this analysis is confined to the period of

Table 4 e-NAM trade as a share of production and value

States	Paddy (m t)		Wheat (m t)		Foodgrains (m t)		AgGVA in 2018-19 (Rs '000 crores)	Total e-NAM trade value 2020-21 (Rs crores)	Share of e-NAM trade in AgGVA of 2018-19 (%)
	Produ-ction	e-NAM trade	Produ-ction	e-NAM trade	Produ-ction	e-NAM trade			
				2019-20					
Haryana	4.82	1.69	11.88	0.00	17.86	1.72	62.9	9,381.6	14.9
Madhya Pradesh	4.78	0.11	19.61	0.30	33.52	1.00	221.1	1,430.1	0.6
Uttar Pradesh	15.52	0.29	33.82	0.22	56.17	0.59	233.7	476.4	0.2
Telangana	7.43	0.28	0.01	0.00	11.13	0.51	49.0	2,407.6	4.9
Punjab	11.78	0.44	17.62	0.00	29.86	0.46	76.5	2,294.1	3.0
Tamil Nadu	7.17	0.38	0.00	0.00	11.27	0.40	83.3	378.0	0.5
Maharashtra	2.90	0.01	1.79	0.03	12.82	0.38	133.5	1,902.6	1.4
Rajasthan	0.48	0.01	10.92	0.12	23.23	0.34	102.1	7,194.8	7.0
Chhattisgarh	6.77	0.11	0.12	0.00	7.50	0.13	35.4	203.9	0.6
Gujarat	1.98	0.00	3.33	0.03	8.15	0.04	111.7	106.7	0.1
Others	41.54	0.03	3.09	0.01	63.45	0.05	627.7	6,133.6	1.0
All-India	118.9	3.34	107.9	0.7	297.5	5.63	1,736.9	31,909	1.8
All-India share of trade in total production (%)		2.82		0.66		1.89			
				2020-21					
All-India e-NAM trade quantity, 2020-21 (mt)		2.73		0.52		4.74			
Share of trade in total production of 2019-20 (%)		2.30		0.48		1.59			

Source Same as in Table 1.

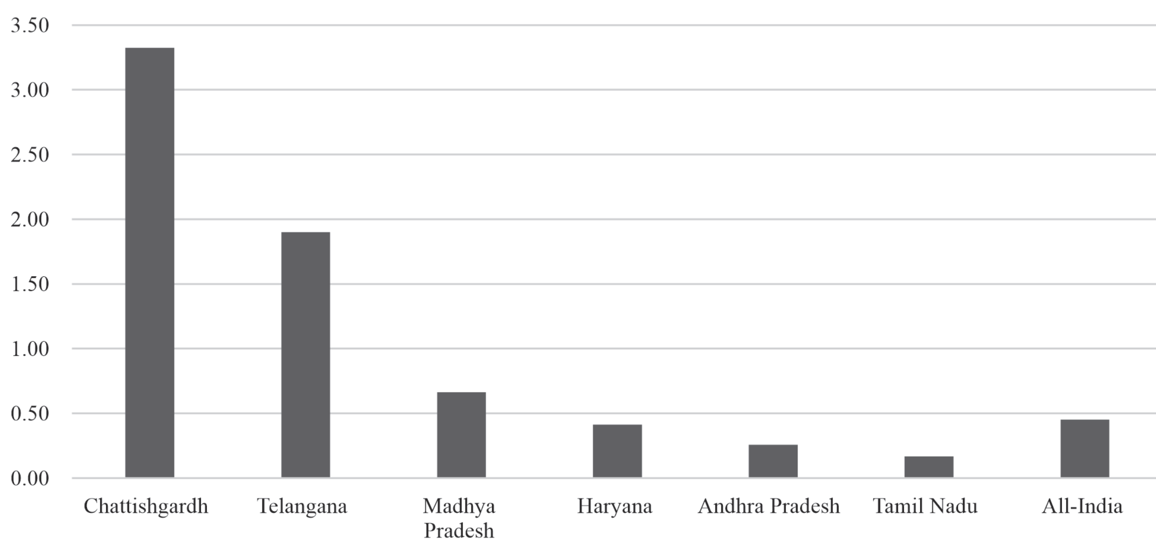

Figure 2 Inter-market trade value share in total trade during Jan 2018 to Dec 2019 (%)

Jan 2018 to Dec 2019. The value of trade shows that almost 99.5% of it happens through e-tendering, which indicates that the offline transactions that happened in APMC markets are just digitalized, ensuring transparency. But, to reap the full benefit of e-NAM, a substantial amount of inter-market transactions needs to occur to increase trade competitiveness and ensure better prices to farmers.

Determinant of e-NAM trade performance

We assessed determinants of e-NAM trade using the least square dummy variable (LSDV) regression. Farmers' participation, the share of non-foodgrains in total trade, and incentives appear as important factors positively influencing the value of trade. Farmers' participation is directly related to the value of trade, and on average each additional farmer would enhance trade value by 0.11%. The nature of commodities being traded also influences the value of trade. On average a one-percent increase in the share of non-foodgrains leads to a 0.025% increase in the value of trade. Further, the states that provide monetary incentives to stakeholders for participating in e-NAM trade, realize an average 2.3% higher trade through e-NAM. The infrastructure and buyer-related factors show neither coverage by e-NAM coverage nor traders' intensity and their licenses have a significant effect on the value of trade. As of now, intra-market trading is the most common phenomenon, while Unified license is an essential requirement for inter-market trading. Also, given the size of farmers' participation, the existing trader density is enough for handling the products. The differential intercept time dummy is also not significant.

The effect of e-NAM on farmers' price

Overall, it is observed that e-NAM prices are relatively lower compared to the Agmarknet prices. However, exceptions are also noticed. For instance, paddy prices are higher in e-NAM markets of Punjab and Haryana than their corresponding Agmarknet prices. It is plausible that most of their non-basmati paddy is procured by the Food Corporation of India (FCI) and the basmati paddy could have been traded in the e-NAM. Thus, we have dropped these two states from the price difference analysis. Groundnut in Tamil Nadu and Arhar in Karnataka are the other exceptions, where e-NAM prices are reported to have outpaced the Agmarknet prices. Additionally, it is also observed that farmers have not realized MSP for most crops in most of the states.

Out of 35 Wilcoxon price difference tests conducted across states for eight commodities, eight tests produced insignificant results indicating prices are more or less equal in both the markets at the state level. And, four tests supported the hypothesis of positive and significant effect of e-NAM on farmers' prices (in case of paddy in Uttar Pradesh (Rs 31/Qtl), Arhar in Karnataka (Rs 333/ Qtl), groundnut in Tamil Nadu (Rs1580 / Qtl), and soybean in Rajasthan (Rs59/Qtl). Two-thirds of the tests supported the hypothesis that e-NAM prices are lower than Agmarknet prices.

Table 5 Determinants of e-NAM trade performance

Dependent Variable: Proportion of e-NAM Trade value in state agricultural GVA (%)

Variables	Coefficients	Standard Error	P-value
Intercept	-1.804	0.891	0.055
The proportion of regulated markets on e-NAM (%)	-0.036	0.056	0.530
Farmers' participation (%)	0.114	0.016	0.000
Traders per GCA (No./lakh ha)	0.008	0.006	0.164
Proportion of traders received unified licence (%)	-0.017	0.010	0.117
Share of non-foodgrains in the total value of trade (%)	0.025	0.013	0.062
Policy incentives (If incentives =1; Otherwise=0)	2.317	0.939	0.022
Time dummy (2019-20 =0 and 2020-21=1)	0.235	0.713	0.745
R Square	0.82		
Adjusted R Square	0.76		
Number of observations	30		

Table 6 Results of Wilcoxon signed-rank test of the price difference between e-NAM and Agmarknet markets

Crops	Major States	No. of paired observations	e-NAM price difference over Agmarknet		Z-statistic	P-value
			Number of negative signs	Average price difference (Rs/Qtl)		
Paddy	Uttar Pradesh	24	8	31	1.91	0.056
	Chhattisgarh	21	12	-37	-1.83	0.068
	Telangana	22	21	-112	-4.07	0.000
	Tamil Nadu	22	13	-145	-1.51	0.131
	West Bengal	20	20	-234	-3.92	0.000
Wheat	Chhattisgarh	24	13	50	0.23	0.819
	Rajasthan	24	20	-51	-3.66	0.000
	Madhya Pradesh	24	22	-51	-3.37	0.001
	Uttar Pradesh	24	22	-58	-3.51	0.000
Maize	Tamil Nadu	22	10	16	0.71	0.475
	Andhra Pradesh	21	9	-5	0.47	0.639
	Madhya Pradesh	24	15	-23	-1.11	0.265
	Maharashtra	24	16	-60	-1.91	0.056
	Telangana	23	17	-799	-3.20	0.001
Arhar	Karnataka	18	1	333	3.68	0.000
	Telangana	24	12	34	-0.11	0.909
	Maharashtra	24	23	-236	-4.26	0.000
	Uttar Pradesh	13	8	-288	-1.78	0.075
	Gujarat	18	12	-334	-1.89	0.058
Groundnut	Tamil Nadu	23	3	1580	3.77	0.000
	Andhra Pradesh	21	8	44	0.92	0.357
	Rajasthan	24	18	-139	-1.91	0.056
	Gujarat	17	16	-690	-3.57	0.000
	Maharashtra	21	13	-729	-1.62	0.106
Mustard	Haryana	15	8	-10	-0.51	0.609
	Rajasthan	24	20	-185	-3.77	0.002
	Madhya Pradesh	24	22	-370	-3.74	0.000
	Uttar Pradesh	24	24	-469	-4.29	0.000
	Gujarat	14	12	-589	-2.73	0.006
Soybean	Rajasthan	18	17	59	-2.19	0.029
	Chandigarh	24	15	-107	-1.20	0.230
	Madhya Pradesh	24	17	-194	-2.37	0.018
	Maharashtra	23	21	-216	-3.80	0.000
	Telangana	24	17	-681	-3.59	0.000
Copra	Tamil Nadu	22	22	-1135	-4.11	0.000

e-NAM trading process

Based on the focused group discussion with mandi officials, traders, and farmers in Tamil Nadu, we discuss the e-NAM trading process and constraints in its adoption. The farmers need to bring their products to the market. At the gate, registration, weighing will be done and a lot number will be generated. For farmers' registration, identifying proof and bank account details are required. Farmers need to register only one time in any market and this ID can be used for future transactions. However, there is no unique ID for farmers to trade across markets, hence, they need to do registration in each market separately.

Traders and commission agents also essentially need to do registration to do trading in e-NAM. For the traders, the registration is done at two levels APMC level -(--trading can only be done at a particular APMC) and state-level (--trading can be done across the states). The APMC level registration is approved by APMC, while, for state-level registration (unified license) the application will be approved by State Agricultural Marketing Board. Finally, the unified license with a unique ID will be provided by Nagarjuna Fertilizers and Chemicals Ltd (NFCL), Hyderabad, the strategic partner and the service provider for eNAM (SFAC 2021). In Tamil Nadu, farmers need to pay neither a registration fee nor a mandi fee. While traders need to pay license fees and mandi fees at the rate of one percent of the value of trade.

After the lot number is generated, a sample will be collected for quality assaying. Then, the complete details like commodity name, and varieties, quantity along quality parameters will be uploaded in the online portal. For each market, the opening and closing times for bidding will be varying. After the closing time of bidding, the system will identify the bid winner based on the highest bid for each lot and SMS also will be sent to the farmers for price confirmation. If the price is agreed upon, a sale agreement report will be generated and given to both farmers and traders. The trader needs to deposit the amount in the concerned APMC account, either online or at the bank, and lift the product from the APMC. From the APMC account, the mandi officials will transfer the money to the farmer's account on the same day, in some occasions, the delay is also reported maximum of three days. If the farmer is not satisfied with the price, he can reject the sale. After rejection, the farmer has two options. First, he can store the product at the APMC godown and sell it in the coming days and there is no storage cost for farmers for 15 days, after that Rs 0.4/qtl per day is charged. Second, farmers can take back the product for selling other outlets or storing it at their homes.

Stakeholders' perception and constraints in e-NAM trading

Farmers

The majority perceived that e-NAM reduced their marketing costs. Because, online trading eliminated 2% commission charged by the traders and other hidden charges, also ensured proper weighment. They believed e-NAM prices are more or less equal to other marketing outlets, but the absence of other charges benefitted them for participation in e-NAM. However, farmers also reported some of the constraints in e-NAM compared to their traditional market outlets, like waiting at the APMC till the product is being sold and delay in receipt of payment (2-3 days), and apprehension about non-sale in online and subsequent cost of return transportation charges. In the traditional market, the product is being sold at the farm gate or commission mandi, the product is sold immediately and the amount is also settled right away after adjusting advance if any taken. Some of the farmers are not much aware of the e-NAM process and price confirmation also through personal contact of e-mandi officials not through SMS, as reported in the e-NAM trade process.

Traders

Traders are not in favour of online trading, as they are facing difficulties in coping up with digitalization, and also it affects their income. They contend that e-NAM made them dependent on someone well-versed with digital transactions for their transactions-mostly their relatives or staff at the internet cafe. Some traders reported that they have been forced to buy a computer or laptop, as the mobile e-NAM app is not as convenient as the desktop app. For instance, all the lot they cannot see in mobile app simultaneously and lot details will be visible in reverse order of serial number. They perceive, it makes the bidding process very confusing and cumbersome. But Mandi officials describe that lot order reversal is essential to make aware of buyers the total number of lots and assuring bidding for all lots rather than only initial lots. Traders reported that mismatch in traded quantity is one of the major hurdles in e-NAM. In offline trade, the lots are traded one by one and according to the need, traders purchased quantity. While in online trade, simultaneous bidding causes difficulty, either winning the lots more than demand or nil, both are troublesome to traders. Traders also reported that during the bidding process, there are no options in the system for save, reviewing the bids which make them bidding a nightmare. On the other hand, they also face monetary losses, one of the main losses for traders is the commission from farmers. Additionally, they need to pay a mandi fee in e-NAM, while outside e-NAM transactions are also supposed to report and deposit mandi fees at the respective APMCs, but in general, the transactions are underreported or unreported.

e-Mandi officials

The e-NAM officials the gross-root level implementation agents are finding it a tough time to transition from offline trading to online mode. The time for commodity arrival to trading is very short. Specifically, that is all the operations like lot number generation, quality assaying, uploading the lot details in the portal need to be carried out within 3-4 hours. Some of the officials reported that during the peak harvesting seasons of paddy daily 100 -150 farmers will visit the APMC market and the limited staff compels them to skip quality testing and grading will be done based on the inspection. Kumar et al. (2020) also reported the skipping of quality testing during peak marketing seasons in their study. It makes the reliability of the grading system highly questionable. Subsequently, buyers lose confidence in the grading system and they examine the lot physically before bidding the prices. NABARD (2018) study also noted that neither farmers nor traders are trusting the quality assaying. It has serious implications for inter-market trading, as the traders located in other places would not participate or need to employ the agent to verify the quality of the product. Eventually, the very purpose of online marketing is defeated. Also, this inefficiency in the system increases the transaction cost of buyers. Further, it is also observed that the difference in the bag size complicates the bidding process and hinders inter-market trading. For instance, paddy is packed in varying quantities in the different areas say 60 kg, 75 kg, 80 kg, and prices are quoted per bag rather than quintal.

Conclusions and implications

We analyzed the e-NAM performance and progress and its effect on farmers' prices. The e-NAM, still need to go long way to achieve set targets. Only about 15% of the APMC markets are linked and farmers' participation rate also wobbling around 13%. The major commodities traded are cereals which account for nearly 40% of total volume and 25% of the value of trade in 2020-21. The trade concentration analysis also indicated a moderate to the high concentration of trade in the majority of the commodities, highlighting only certain states are actively participating in e-NAM. Monetary incentives and farmers' participation rates are the major factors that influence the value of trade. We find the e-NAM prices are significantly lower than the Agmarketnet prices in most commodities in the majority of the states. And, only a very few states recorded the higher prices in some commodities. A very little amount of total products is being traded through e-NAM. Also, inter-marketing trade is negligible which could be one of the reasons for not increasing the competition and achieving better price realization. Reddy and Mehjabeen (2019) also reported no significant increase in competition as the flip side of e-NAM. The benefit of online trading could be realized not only by linking more markets but also by the active participation of buyers across the markets. But our analysis pointed out that in general, trading through e-NAM is very low and inter-market trading is negligible. Therefore, we suggest the following strategies to promote both intra-market and inter-market trading.

- A unified license is the pre-requisite for inter-market trading, hence, acceleration of the speed of license issue is the pressing priority.
- Although infrastructure is available, there is a lack of skilled manpower and training for establishing standard quality assaying labs. Hence, addressing these issues and building confidence in quality testing and grading system among the buyers is an essential need to improve the efficiency of the system.
- Development of a uniform price quote system like price per unit of a product like Rs/qtl or Rs/kg rather than Rs/bag would ease the bidding process.

- The technical glitches in the online system need to be addressed to attract more traders. For example, save and review options need to be provided as it is very essential especially power and internet interruptions. More user-friendly options like a drop-down menu to choose the particular lots for bidding rather than scrolling down the lots.
- Also, the bid winners' list in a day for all the lots listed is based on the order of highest bid-wise rather than a serial number of the lots. But the option should be given to e-mandi officials to print the result as per their convenient ordering. Because, when SMS service for price finalization is failed, the e-mandi officials face difficulties in declaring the results.
- During the survey and previous study (Kumar et al. 2019), farmers reported that lack of awareness is the major reason for the low participation of farmers. Hence, a large-scale awareness campaign needs to be done to bring more farmers into e-NAM.

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Economic access to groundwater irrigation under alternate energy regimes in Bihar

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Abstract With abundant groundwater resources, Bihar has the potential to harness the positive groundwater and agricultural development linkages by improving the economic access to groundwater irrigation. Using the representative data from Central Groundwater Board and the 5th Minor Irrigation Census, this study has examined the spatio-temporal changes in groundwater level, and compared the groundwater extraction cost under different energy policy regimes. The analysis shows a stable groundwater level in large parts of the state. The majority of the groundwater pumps are dependent on diesel energy, which is more than four times costlier than electric energy. Electric pumps are economical than diesel pumps even without the power subsidy. As the power supply in the state has been improving, farmers can significantly reduce irrigation costs by shifting to electric pumps. Among the electric pump owners, farmers with metered pricing (pro-rata) incur less energy cost as compared to flat-rate pricing. Bihar presently has both flat and pro-rata based pricing policies for electric pumps, leading to a trade-off between economic and equity aspects of groundwater use which needs to be optimized.

Keywords Groundwater, Energy, Pricing policy, Bihar

JEL Codes Q25, Q28, Q41, Q42

Over the years, groundwater has emerged as a predominant irrigation source in India due to its reliable supply compared to canal water. This is reflected from an increase in its share in net irrigated area, from 30.36% in 1964-65 to 64.10% in 2015-16. As agriculture is heavily dependent on groundwater, efficient management of groundwater resources is crucial to sustaining food security. There exists a wide spatial heterogeneity in groundwater use. While groundwater is over-exploited in the north-western and parts of the southern region of India, it remains under-utilized in the eastern region on account of several economic and non-economic reasons (Srivastava et al. 2012). Even in the water surplus eastern India, where groundwater is largely under-utilized at the aggregate level, a few areas have started witnessing groundwater depletion (Srivastava et al. 2018). Under-development of groundwater resources in eastern states leads to the loss of opportunity to harness the positive groundwater and agricultural development linkages (Srivastava et al. 2014). At the same time, groundwater depletion poses a threat to the ecological balance and leads to inequality in its distribution with adverse financial implications for the farmers (Sarkar 2011). Therefore, promoting 'sustainable' utilization of groundwater resources in the eastern region remains a critical agenda for balancing the trade-off between economy and ecology.

Given the widespread poverty in eastern states (Alkire et al. 2021), economic access to groundwater is a major challenge in promoting groundwater use for irrigation. As the majority of groundwater pumps in eastern states are operated using costlier diesel energy (Foster et al. 2021), there exists a potential to reduce the groundwater extraction cost and improve economic access to groundwater by providing a reliable and cheaper alternate source (e.g. electricity and solar) to energize groundwater pumps. This study has evaluated such prospects in the state of Bihar, where the overall stage of groundwater utilization is 46% (CGWB 2019) and 89% of the wells are energized using diesel energy (GoI 2017). Kishore (2020) has found that irrigation in Bihar is expensive which forces farmers to over-economise on water application with negative consequences on agricultural outcomes such as low crop yields, high vulnerability to draughts and heatwaves, and low cropping intensity. As the power supply situation in Bihar has been improving (Kishore 2020), it is imperative to empirically assess the economic aspects of groundwater irrigation under alternate energy policy regimes. The study has two objectives: (1) examine spatial variation and temporal changes in groundwater level, and (2) estimate and compare groundwater extraction cost under different energy policy regimes. The findings provide an empirical basis for promoting economic access to groundwater and its sustainable use in agriculture in Bihar.

Data and methodology

Spatial variation and temporal changes in groundwater level in Bihar have been examined using the groundwater level data at the monitoring wells of the Central Groundwater Board (CGWB). In the year 2019, CGWB monitored groundwater levels at 620 monitoring wells in the state in both pre-monsoon and post-monsoon seasons. To understand spatial variation, these wells were geo-located and groundwater levels were spatially interpolated using the Inverse Distance Weighting (IDW) method in ArcGIS software. IDW is a deterministic method for multivariate interpolation approach to estimate an unknown value at a location with a weighted average of the values available at the known points.

Further, changes in groundwater level were examined during the period 2008 to 2019. For this, only those wells were considered for which at least nine years of consistent data are available. Following Srivastava et al. (2018), Mann-Kendall (MK) test was applied to test significant monotonic increase/decrease in groundwater level during 2008 to 2019 at each monitoring well. Thereafter, Sen's slope was estimated to measure the magnitude of the trend (change per unit of time) in groundwater level.

MK test is a non-parametric method to assess the monotone increase or decrease in a given time series and can be suitably used for the series with missing data and skewed values. In this method, Kendall's S-statistics is computed by comparing the later measured values with the earlier measured values for n(n-1)/2 possible pairs of data for n observations. Kendall's S-statistics is computed as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(y_j - y_i) \qquad \ldots(1)$$

Where,

$$sign\left(y_j - y_i\right) = \begin{cases} = +1 \; if \; \left(y_j - y_i\right) > 0 \\ = 0 \; if \; \left(y_j - y_i\right) = 0 \\ = -1 \; if \; \left(y_j - y_i\right) < 0 \end{cases} \qquad \ldots (2)$$

Large positive values of S indicate an increasing trend and large negative values indicate a decreasing trend with time. For a time series of more than equal to 10 years (n ≥ 10), the MK test statistics is near normally distributed.

Sen's slope measures the magnitude of the trend (change per unit time) in groundwater level. To derive an estimate of the slope β, the slopes of all data pairs are calculated as:

$$\beta_i = \left(\frac{y_j - y_k}{t_j - t_k}\right) \qquad \ldots(3)$$

Where, i=1,2,…, N, J>k, y_j and y_k are measurements at times t_j and t_k, respectively. If there are n values y_j in the time series, we get as many as N= n(n-1)/2 slope estimates β_i. The Sen's slope estimator is the median of these N values of β_i. The N values of β_i are ranked from the smallest to the largest and the Sen's slope is given by

$$\beta = \begin{cases} \beta_{\frac{N+1}{2}} \; if \; N \; is \; odd \\ \frac{1}{2}\left(\beta_{\frac{N}{2}} + \beta_{\frac{N+2}{2}}\right) \; if \; N \; is \; even \end{cases} \qquad \ldots (4)$$

Economic access to groundwater irrigation under alternate energy regimes was examined by estimating groundwater extraction costs. The total cost of groundwater extraction comprises the amortized fixed cost of constructing wells and installing pump sets, and the variable cost of energy (diesel/electricity) use. As shallow tubewells are predominant groundwater structures in Bihar, the cost calculations were made for these types of wells.

The fixed cost (including the cost of construction of wells and installation of the machine) of the functional wells constructed in the year 2013-14 was taken from the 5th MI census. This cost was inflated for 2019-20 using the wholesale price index of irrigation machines which increased at the rate of 2.34% per annum during 2013-14 to 2019-20. For amortization of fixed cost, the rate of interest is assumed 6% and the expected life of 10 years for diesel pumps and 15 years for electric pumps). The formula for amortizing the fixed cost is:

$$AC = \frac{CB \times (1+i)^n \times i}{(1+i)^n - 1} \qquad \ldots(5)$$

Where, AC = annual amortized cost (Rs), CB = initial cost of constructing wells and installing pumps (Rs), i = interest rate , and n = life of groundwater structures.

Amortized fixed cost of wells is expressed in terms of per unit volume of groundwater extraction (Rs/m^3). For this, the volume of groundwater extracted for irrigating crops was estimated as follows:

$$\text{Groundwater Draft (lit./sec.)} = \frac{\text{hp} \times 75 \times \text{pump efficiency}}{\text{Total Head (m)}} \qquad \ldots(6)$$

$$\text{Total Head (m)} = \text{Water table (m)} + \text{draw down (m)} + \text{friction losses} \qquad \ldots(7)$$

$$\text{Groundwater Draft (m}^3\text{/well/ha)} = \frac{\text{Groundwater Draft (lit./sec.)}}{1000} \times 3600 \times \text{Operating hours (hours/ha)} \qquad \ldots(8)$$

The information on horsepower (hp) of the pump and operating hours were taken from the 5th MI census. The values of draw-down for dug wells, shallow tubewells and deep tubewells was assumed as 1, 2 and 4 m, respectively. Friction losses were assumed as 10% of the water table and drawdown. The information on the water table was taken from CGWB.

Energy cost was calculated by multiplying prevailing energy prices (for diesel and electricity) with the estimated energy used (1 hp = 0.746 Kilowatt) per unit volume (m^3) of groundwater. The energy cost was estimated separately for diesel and electric operated pumps. Further, Bihar has both subsidized flat-rate and subsidized pro-rata tariff systems for supplying electricity to groundwater pumps. Energy costs were calculated under these energy regimes and compared with each other.

Results and discussion

Status of groundwater resources and use

Bihar is endowed with rich water resources due to the high precipitation, extensive river basin network, and alluvial aquifer with significant storage space for groundwater. On average, the state receives annual precipitation of 120 centimetres. Rainfall is a major source of groundwater replenishment, contributing 74% to the total groundwater recharge. The net annual groundwater availability for different uses is 29 billion cubic meters (BCM). But, only 46% of the available groundwater is extracted, implying an under-utilization of available groundwater resources at the aggregate level (CGWB 2019). As groundwater is largely under-utilized, there exists a huge scope to accelerate sustainable use of groundwater for harnessing a positive groundwater-agricultural development linkage. Although evidence at the aggregate level indicates the under-utilization of groundwater resources in Bihar, there are few areas with depleting groundwater levels as well. This is indicated by the categorization of 13% (72 numbers), 3% (18 numbers) and 2% (12 numbers) of total administrative blocks (534) in the state as semi-critical, critical, and over-exploited, respectively (CGWB 2019). Irrigation being the predominant consumer of groundwater bears the prime responsibility of using this resource sustainably. Presently, groundwater irrigates 63% of the net irrigated area and its share has been rising.

Spatial variations and temporal change in groundwater level

According to the data from CGWB, the average groundwater level in Bihar was 6.37 meters below ground level (mbgl), varying from 0.74 mbgl to 16.11 mbgl in the pre-monsoon season (May) of 2019 (Table 1). About 92% of the wells have a shallow water level of fewer than 10 mbgl and 8% have a water level of more than 10 mbgl. It is to be noted that at groundwater level higher than 8-10 mbgl, centrifugal pumps become inefficient and need to be replaced with submersible pumps for groundwater extraction (Sekhri 2013). The

Table 1 Groundwater levels in Bihar in 2019

Season	Groundwater level (m bgl)	Distribution of monitoring wells across groundwater level (%)						Total wells (no)
		0-2	2-5	5-10	10-20	20-40	>40	
Pre-monsoon (May)	6.37 (0.74-16.11)	2	35	55	8	0	0	621
Post-monsoon (November)	3.28 (0.02-14)	29	54	16	1	0	0	627

Note Figures within parentheses are minimum and maximum values of observed groundwater levels at monitoring wells
Source Authors' calculations based on data of CGWB. http://cgwb.gov.in/GW-data-access.html

prevalence of shallow groundwater depth in most parts of the state offers scope to sustainably and economically utilize groundwater resources and harness productive groundwater-agricultural development linkages in the eastern region (Srivastava et al. 2014). Further, in the post-monsoon season, groundwater level goes up by about 3 mbgl from the pre-monsoon level improving the prospects of physical and economic access to groundwater. The rising groundwater level in the post-monsoon season is evident from the shifting distribution of monitoring wells towards lower groundwater level categories.

The evidence shows that groundwater level in 29% of wells in Bihar rises upto 2 mbgl which is a water-logging situation. A persistent water-logging in the root zone (0-3 mbgl) is not conducive for optimum crop growth and requires effective drainage of the excess water. Among various technologies for excess water conditions, the installation of low horse-power solar pumps can be promoted to withdraw the surplus water and provide assured irrigation to the crops. On the other hand, it is essential to keep monitoring the groundwater level in the wells located in the areas with deeper groundwater levels.

Figure 1 shows the spatial heterogeneity and temporal changes in groundwater level in pre- and post-monsoon seasons. The groundwater in north Bihar is at a shallower level as compared to that in South Bihar. During the pre-monsoon season, the groundwater level in most of the north Bihar remains below 5 mbgl, whereas in south Bihar it goes up to 10 mbgl. A substantial recharge takes place from rainfall during the monsoon season and the volume of groundwater extraction remains lower than the recharge. Subsequently, the groundwater level rises in most of the areas of the state in the post-monsoon season. This is visible from the shifting area from the category of 3-5 mbgl groundwater level in the pre-monsoon season to the category of <3 mbgl groundwater level in the post-monsoon season in north Bihar. Similarly, rising groundwater levels can also be seen in South Bihar after the monsoon season. Such inter-seasonal changes in groundwater levels reveal ample scope to accelerate groundwater use for productive purposes.

For the sustainable management of groundwater resources, groundwater levels should be stable over the long run in both pre-monsoon and post-monsoon seasons. A comparison of maps of groundwater level (pre-monsoon) from 1997 to 2019 provides some signs of groundwater depletion in a few pockets in the last ten years (2008 and 2019). Therefore, a detailed examination of the long-run trend in groundwater level at monitoring wells of CGWB was undertaken by applying the Mann Kendall test and estimating Sen's slope.

The MK test was applied at each of the 228 monitoring wells separately during the pre-monsoon and post-monsoon season for the period 2008-2019. The results reveal no significant change in groundwater in more than 70% of the wells in pre- as well as post-monsoon seasons (Table 2). This implies that the groundwater level is largely stable in the state. Further, 12% of the wells witnessed a rising trend in groundwater level in the pre-monsoon season at an average rate of 16 centimetres/annum from 2008 to 2019. Interestingly, the number of the wells witnessing a significant rising trend doubled in the post-monsoon season. On the other hand, 14% of the wells witnessed a significant declining trend at an average annual rate of 23 centimetres in the pre-monsoon season. But, the number of wells witnessing a declining trend reduced to half (7%) in the post-monsoon season during the period under

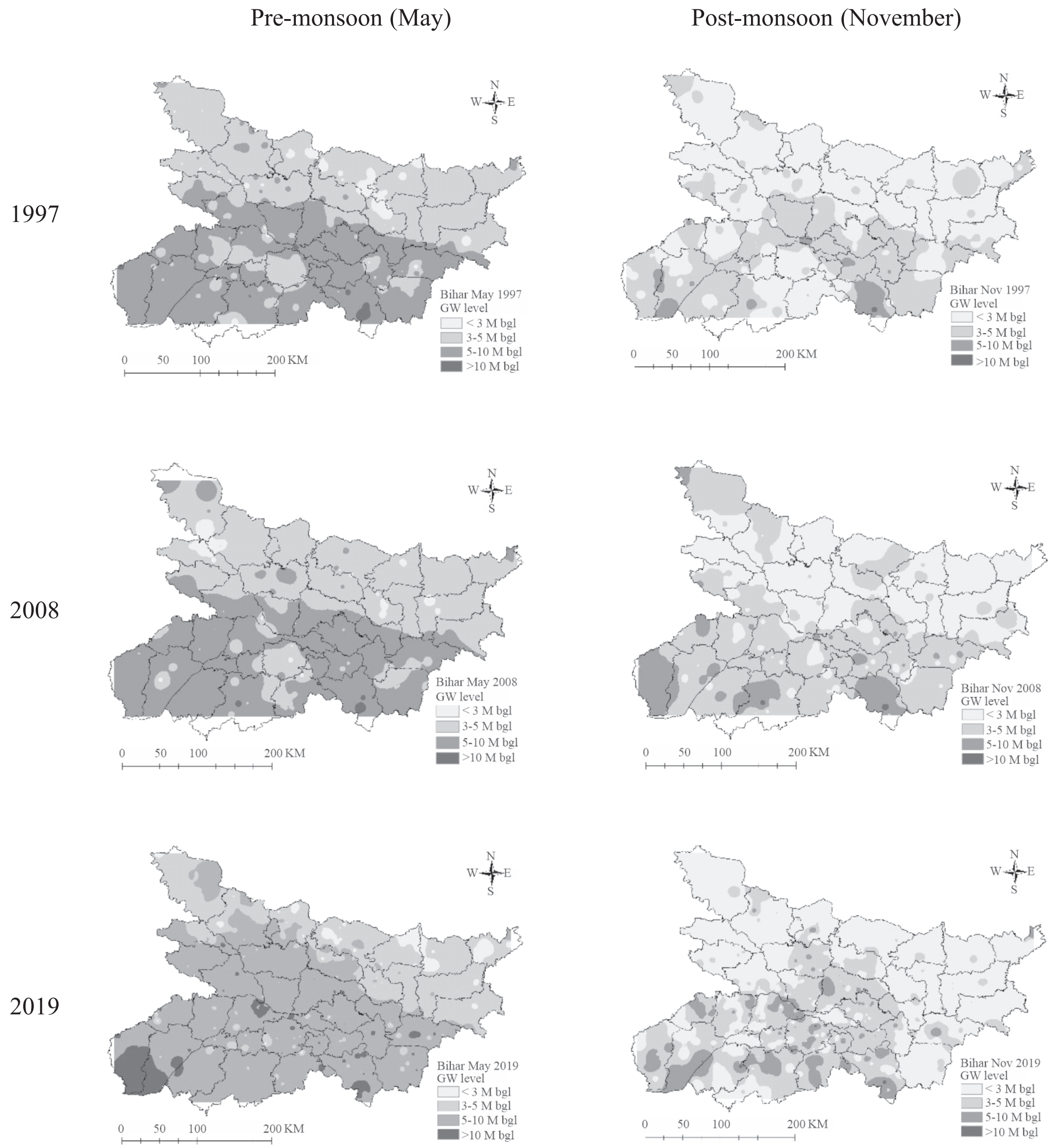

Figure 1 Spatial variation and temporal changes in groundwater level
Source Authors' analysis based on data of CGWB. http://cgwb.gov.in/GW-data-access.html

Table 2 Trends in groundwater level during 2008 to 2019 in Bihar (Mann-Kendall test and Sen's slope estimator)

Season	Particulars	No significant trend	Significantly rising trend	Significantly declining trends	Total wells (no.)
Pre-monsoon	Wells (%)	73	12	14	228
(May)	Sen's Slope (cm/year)	1	-16	23	
Post-monsoon	Wells (%)	70	23	7	228
(November)	Sen's Slope (cm/year)	-3	-14	25	

Source Authors' estimates

consideration. This implies that the water level in about half of the wells witnessing a declining trend in the pre-monsoon season recovered (with either no trend or rising trend) in the post-monsoon season. Overall, stability in groundwater level or rising groundwater level shows scope to sustainably promote groundwater use. At the same time, careful groundwater monitoring and control are required in the areas witnessing declining groundwater levels in both pre- and post-monsoon season (7% of the wells).

Structure of groundwater irrigation

According to the 5th Minor Irrigation (MI) Census, there were 6.44 lakhs groundwater structures for withdrawal of water for irrigation in Bihar up to the year 2013-14 (Table 3). Between 1986-87 and 1993-94, groundwater structures increased by about two lakhs. In 2000-01, Jharkhand was separated from Bihar, and the number of groundwater structures in Bihar reduced to 7.9 lakhs. Subsequently, total groundwater structures registered a declining trend. It is to be noted that the number of shallow wells increased by 35962 between the last two MI censuses (2006-07 and 2013-14). But, the increase in the number of shallow wells could not outpace the decrease in the number of dugwells and deep tubewells in the state, leading to a net reduction (by 7745) in the total number of groundwater structures. Interestingly, during this period the number of functional wells increased by 32329. The increase in the of functional wells and shallow tubewells in recent years implies a rising trend in the construction of new groundwater structures in Bihar, whereas traditional groundwater structures, like dugwells, are going out of use.

The analysis reveals that the dugwells are being substituted by shallow tubewells. At present, shallow tubwells are the predominant groundwater structure in the state. Surprisingly, the number of deep tubewells have declined in recent years.

Energy use pattern for groundwater irrigation

Successive MI censuses reveal that most of the groundwater structures in Bihar are energized by diesel (Table 4). According to the latest (5th) MI Census (2013-14), about 89% of wells relied on diesel for extracting groundwater for irrigation. The predominance of diesel as the energy source was primarily due to the low levels of electrification and unreliable supply of electricity (Hoda et al. 2021). Further, shallow water levels and

Table 3 Changing composition of groundwater structures

Year	Total number of wells (no.)				Composition of wells (%)		
	Dugwells	Shallow Tubewells	Deep Tubewells	Total	Dugwells	Shallow Tubewells	Deep Tubewells
1986-87	337624	429046	14957	781627	43.2	54.9	1.9
1993-94	391198	589519	6440	987157	39.6	59.7	0.7
2000-01	135177	651383	6190	792750	17.1	82.2	0.8
2006-07	56112	571871	23259	651242	8.6	87.8	3.6
2013-14	22877	607833	12787	643497	3.6	94.5	2.0

Source Authors' calculations based on successive minor irrigation census data

Table 4 Distribution of groundwater wells according to energy sources (wells with one energy source)

(%)

Year	Electricity	Diesel	Others	Total wells (no)
1993-94	5.4	70.9	23.7	980717
2000-01	5.2	86.0	8.8	786560
2006-07	0.0	0.0	100.0	651242
2013-14	6.7	88.9	4.3	482826

Source Authors' calculations based on successive minor irrigation census data fragmented land holdings prompt farmers to use low-power diesel-operated centrifugal pumps as these pumps can be easily transported and used with different borings.

With the rising diesel prices, extracting groundwater for irrigation has become costlier. Simultaneously, infrastructure for electricity supply is improving. Thus, farmers are gradually shifting from diesel to electricity for energizing pumps. The evidence from MI Censuses shows a rising share of electric-operated pumps in the state. The share of groundwater structures energized using electricity in total structures (with a single energy source) increased from 5.4% in 1993-94 to 6.7% in 2013-14. Although farmers are gradually shifting towards electricity, a majority of the groundwater pumps are dependent on diesel.

Cost of groundwater extraction under different energy regimes

Among several direct and indirect factors, access to reliable and cheaper source of energy is a critical factor indirectly affecting the extent of groundwater use for irrigation. It is essential to assess the financial implications of using alternative energy sources for groundwater irrigation. As diesel and electricity are two major sources to energize groundwater structures, the cost to extract a unit volume of groundwater for irrigation has been estimated and compared between diesel and electric operated pumps for the reference year 2020-21.

Table 5 presents the cost incurred in groundwater extraction by the predominant shallow tubewells. The results show that a shallow tubewell operated using diesel incurs Rs 2.40 to extract one cubic meter (m^3) of groundwater. On the other hand, an electric shallow tubewell incurs Rs 0.60/m^3, which is four times less as compared to diesel pumps. Such a large difference in the cost between diesel and electric pumps is primarily accounted for by differences in the energy costs and the utilization levels of the pumps. Note, the fuel cost accounts for half of the total cost of operation of a diesel pump. Further, the data from the 5th MI Census show that electric pump owners operate their pumps for a longer time. Therefore, a higher utilization level of electric pumps also results in lower groundwater extraction costs. There is ample scope to diversify energy sources towards electricity by improving the power supply infrastructure. The electricity supply for irrigation in Bihar has improved in recent years and the farmers are gradually switching from diesel to electric pumps.

Bihar has pro-rata and flat-rate tariff systems for metered and unmetered connections, respectively. For the metered connections, farmers were charged a highly subsidized electricity tariff of Rs 0.70/unit in 2020-21 and the government provided a subsidy of Rs 4.75/unit (plus fixed charges of 30/Hp). The farmers with unmetered connections were charged a monthly flat rate of Rs 84/Hp with the subsidy grant of Rs 716/hp/month. The average diesel price in Bihar in 2020-21 was Rs.90.95/l. A comparison of energy costs under different price policy regimes shows that farmers incur the lowest energy cost in the pro-rata based tariff system (Table 6).

With the same utilization level of pumps, energy cost per unit volume of groundwater extraction under a flat-rate tariff system would be 6.75 times higher than in the pro-rata based tariff system. Lower energy cost under the pro-rata tariff system provides an economic rationale to install meters on the electric-operated pumps. This will further reduce the inefficient use of groundwater as the positive marginal cost will incentivize farmers to reduce inefficient use of groundwater. However, a flat-rate tariff has the potential to promote more equitable groundwater markets as pump-owners who pay a flat tariff can sell

Table 5 Cost of groundwater extraction by shallow tubewells in Bihar in 2020-21

Total cost (Rs/m^3)			Share of energy in total cost (%)	
Diesel	Electricity	Ratio of total cost with diesel and electricity	Diesel	Electricity
2.40	0.60	4.02	48	7

Source Authors' calculations

Table 6 Energy cost and the total cost incurred by shallow tubewells under different energy sources and regimes in 2020-21

Energy cost (Rs/m^3)			Total cost (Rs/m^3)		
Electricity (Metered)	Electricity (Flat rate)	Diesel	Electricity (Metered)	Electricity (Flat rate)	Diesel
With electricity subsidy					
0.04	0.27	1.01	0.60	0.81	2.40
Without electricity subsidy					
0.28	2.58	1.01	0.85	3.11	2.40

Notes Electricity tariff in Bihar: Rs 0.70/unit for metered connections and Rs 85/hp/month for unmetered connections in 2020-21. The government paid a subsidy of Rs 4.85/unit (plus fixed charges of 30/hp) for metered connections and Rs 716/hp/month.
Diesel prices: Rs 90.94/litre in Bihar in 2020-21
Source Authors' calculations

groundwater without incurring marginal costs on energy. Further, energy cost under subsidized pro-rata as well as flat-rate systems was found to be significantly cheaper than the energy cost with diesel. Thus, under the prevailing energy pricing scenario, it would be economical for the farmers to shift from diesel to electricity as the source of energy for irrigation. Even if the subsidy on the electricity is removed, the energy cost of pumping groundwater at the full cost of electricity supply (Rs 5.55/unit) would be 2.60 times cheaper than the cost of diesel. Thus, large-scale electrification of wells in the state would significantly reduce the groundwater irrigation cost and improve economic access to groundwater.

Conclusions

At an aggregate level, groundwater resources in Bihar are under-utilized. In most of the areas, groundwater is at a shallow level and even rises in the post-monsoon season from the pre-monsoon level. A majority of the observation wells in the state have seen no significant change in the groundwater level during the past ten years in pre- as well as post-monsoon season. Also about half of the wells witnessing a declining trend in pre-monsoon get recovered in the post-monsoon season. Such evidence unravels the scope to sustainably and economically utilize groundwater resources and unleashes the positive groundwater and agricultural development linkages. Spatially, groundwater in north Bihar is at a shallower level as compared to South Bihar. Further, a few areas in the state are witnessing a depletion in groundwater level and a rise in the level up to the water-logging situation. This underlines a need for constant monitoring and location-specific technological and policy interventions for sustainable management of groundwater resources.

Most of the traditional groundwater structures (e.g. dugwells) in the state are getting obsolete over time and shallow tubewells have emerged as the predominant groundwater structure. With the improving power infrastructure, the number of electric pumps is rising in Bihar. However, a majority of the groundwater pumps are still dependent on diesel energy. There is a huge potential to diversify towards alternative energy sources such as electricity, solar, etc for energizing groundwater pumps. Economically, electric pumps are four times less costly than diesel pumps in the state due to the different energy costs and utilization levels of the two types of pumps. As the power supply in Bihar is improving, it would be economical for the farmers to shift from diesel to electric operated pumps. Even if subsidy on the electricity (under pro-rata tariff system) is removed, it will still be cheaper than diesel. Large-scale electrification of wells in the state would significantly reduce the groundwater irrigation cost and improve economic access to groundwater.

The government of Bihar is implementing both flat and pro-rata electricity pricing systems. With the same level of utilization, farmers in Bihar incur lower energy costs under a pro-rata based subsidized electricity tariff system as compared to the flat rate regime. This provides an economic rationale for the universal meterization of electric pumps in the state. A policy shift from a flat rate to a pro-rata electricity pricing regime would incentivize farmers to reduce inefficient use of groundwater. However, a flat-rate tariff system has the potential to support more competitive groundwater markets as well-owners paying a flat tariff can sell groundwater without incurring marginal costs on energy. Thus, there exists a trade-off between economic and equity aspects of groundwater use which needs to be optimized.

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Role of public policy in sustaining groundwater: impact of 'The Punjab Preservation of Sub Soil Water Act, 2009'

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Abstract Employing the Difference-in-Difference technique to the time series of groundwater level, this study assesses the impact of 'The Punjab Preservation of Sub Soil Water Act, 2009' on the groundwater extraction in Punjab. Over the past two decades, the groundwater level in the state has fallen by 0.43 metres per annum. Our results indicate that even after the implementation of the Act, the groundwater depth in the state has kept on falling, more so in the high rice-growing districts. After the policy change, the groundwater depth in the high rice-growing districts was 1.48 meters lower than in low rice-growing districts.

Keywords Groundwater, Critical stage, Difference-in-difference

JEL Codes C54, O38, Q25

Agriculture relies on both surface and groundwater for irrigation. However, due to the ever-increasing demand for water in agriculture, groundwater has emerged as the dominant source of irrigation. With an annual 251 billion cubic metres (bcm) of groundwater, India is the largest user of groundwater for irrigation in the world (CGWB 2017; Vijayshankar, Kulkarni, and Krishnan 2011). However, the technology-led intensification of agriculture has put excessive pressure on groundwater resources, raising concerns about its effects on the long-term sustainability of agriculture. At least 60% of India's districts are facing the challenge of over-exploitation of the groundwater.

The legal structure in India permits unrestricted free access to groundwater. Riparian rights govern groundwater exploitation, and a landowner has the right to extract groundwater. Groundwater regulation in India operates through state policies, different strategies and instructions (Shah et al. 2001; Shah 2008; Siebert et al. 2010). For example, the state of Punjab provides free electricity to the farm sector. Although, in other states, electricity is not metered; it is provided at a flat rate depending on the pumps' horsepower for lifting the water from under the ground. At the same time, the federal government provides guaranteed minimum support for paddy and wheat, the water-intensive crops.

The federal and state governments have undertaken several initiatives to conserve groundwater resources (Mahajan, Bharaj, and Timsina 2009). However, recognizing groundwater depletion as a serious concern for agricultural growth, the Government of Punjab passed the 'The Punjab Preservation of Sub Soil Water Act, 2009' (hereafter called as Act, 2009). The Punjab government implemented the Act, 2009 to control groundwater depletion through mandatory restrictions on the raising of the paddy nurseries before May 10, and their transplantation before 10th June. The primary purpose of the Act, 2009, was to save groundwater by prohibiting sowing and transplanting of paddy before the specified dates. This paper examines if the Act 2009 could help check the groundwater depletion in Punjab.

Materials and methods

Data and variables

We studied the impact of the Act, 2009, utilizing panel data on 20 districts for 20 years from 1999 to 2018. The study period was divided into two-time slices, i.e., 1999-2008 (pre-Act) and 2009-2018 (post-Act). At present, the state has 22 districts, but due to the non-availability of time series data on the two newly carved districts, viz., Pathankot and Fazilka, these were merged with their parent districts Gurdaspur and Ferozepur, respectively.

The groundwater levels and rainfall data were obtained from the Central Ground Water Board and Indian Meteorological Department. The data on population density were obtained from the Population Statistics of Punjab published by the Economic and Statistical Organisation, Punjab. In addition, we relied on various issues of the Statistical Abstract of Punjab for the data on canal and tube-well irrigated areas and cropping patterns.

Groundwater levels are being monitored by the Central Ground Water Board four times a year. The regime monitoring was started in 1969 by the Central Ground Water Board. There are 23196 observation wells in India, including 984 in Punjab. About 80% of the groundwater observation wells are located in the canal command areas of different canal systems. The minor command areas are part of Pathankot, Hoshiarpur, SBS Nagar, Rupnagar, SAS Nagar, Gurdaspur, Jalandhar and Ludhiana districts. We used groundwater level data compiled from the CGWB to calculate various parameters viz. change in water level from June-over-June and October-over-October, change through June-to-October and October-to-June. The change in water level from June-over-June and October-over-October captures the effect of annual rainfall and other variables. The change through June-to-October depicts the net monsoon recharge in the kharif season. It captures the impact of monsoon rainfall, the paddy area (the main crop that needs water) and other factors such as water management and water-use-efficiency. The change through October-to-June depicts the effect of withdrawals in the rabi season. The withdrawals during the rabi season indirectly affect the monsoon recharge.

Model specification

We used Difference-in-Difference (DiD) approach to study the impact of the Act, 2009. DiD is used to estimate the effect of an intervention by comparing changes in the outcomes over time between a population exposed to the intervention (the treated group) and a population that is not (the control group). Here, the high rice-growing districts were compared with low rice-growing districts before and after the Act, 2009. The districts, whose ratio of area under the rice to the total cultivated area exceeded the sample median (0.6) in 1999, were considered as the high rice-growing (treated) districts and the remaining districts as control. We hypothesized that the Act 2009 affected the groundwater level in the treated districts. Table 1 shows treated and control districts.

The DiD equation cab be written as:

$$Y_{it} = \beta_0 + \beta_1 \text{ Act} + \beta_2 \text{ Tr} + \beta_3 \text{ Act} * \text{Tr} + \beta_4 \text{ Rain} + \beta_5 \text{ CaIrri} + \beta_6 \text{ TbIrri} + \beta_7 \text{ Pd} + \beta_8 \text{ Cdi} + D_i + T_t + \varepsilon_{it} \quad \ldots(1)$$

Where Y_{it} is the annual groundwater level (m) in *i* district at time *t*, Rain is the annual average rainfall (mm), Act is an indicator variable that switches to 1 for the post-Act period i.e. 2009 to 2018 after the Act, 2009 was passed in the Punjab state and equals 0 for pre-act period i.e. 1999-2008. Tr is the treatment indicator that takes the value 1 if the district is treated and is 0 if the district is control. Act*Tr is an interaction

Table 1 High and low rice-growing districts

High rice-growing districts (Treated)		Low rice-growing districts (Control)	
Gurdaspur	Patiala	Jalandhar	Ferozepur
Amritsar	Sangrur	SBS Nagar	Muktsar
Tarn Taran	Barnala	Hoshiarpur	Moga
Kapurthala	Faridkot	Rupnagar	Bathinda
Ludhiana	F. Sahib	SAS Nagar	Mansa

of Act and treatment indicator. CaIrri is the ratio of canal irrigated area to total irrigated area, TbIrri is the ratio of tube well irrigated to total irrigated area, Pd is the population density, and Cdi represents Herfindahl crop diversification index. D_i is the district fixed effects, T_t is year fixed effects and ε_{it} is the error term. Coefficient β_3 (interaction term) is the parameter of interest. It gives the impact of the Act on the groundwater level. Year specific common shocks to all districts of the state are soaked up by the year or time fixed effects. Time invariant district-specific omitted variables that affect the likelihood of treatment are controlled for by including the treatment indicator.

Two specifications of Eq.(1) were estimated. One, only with district and year fixed effects:

$$Y_{it} = \beta_0 + \beta_1 \text{ Act} + \beta_2 \text{ Tr} + \beta_3 \text{ Act} * \text{Tr} + D_i + T_t + \varepsilon_{it} \quad \ldots(2)$$

And, another including all time-varying covariates with district and year fixed effects:

$$Y_{it} = \beta_0 + \beta_1 \text{ Act} + \beta_2 \text{ Tr} + \beta_3 \text{ Act} * \text{Tr} + \beta_4 \text{ Rain} + \beta_5 \text{ CaIrri} + \beta_6 \text{ TbIrri} + \beta_7 \text{ Pd} + \beta_8 \text{ Cdi} + D_i + T_t + \varepsilon_{it} \quad \ldots(3)$$

Unit root test

We tested for the stationarity in the time series by applying the unit root test. The unit root test exhibits whether the data are stationary or non-stationary and avoids spurious regression. As time progresses, the shocks decrease gradually for stationary time series, and there is a possibility that the process reverts to the mean. However, for non-stationary time series, the shocks persist over time, and there is no possibility to completely revert to the mean (Intriligator, Bodkin, and Hsiao 1996). The mean, variance and covariance of stationary data are independent of time. The Levin-Lin-Chu and Harris-Tzavalis unit-root tests were employed (Table 2).

Hausman test

The Hausman test favours fixed effect regression over random effect regression. The fixed effect model is defined as:

$$Y_{it} = \beta X_{it} + \gamma U_i + \varepsilon_{it}$$

Where Y_{it} is the outcome of individual *i* at time *t*, X_{it} is the vector of variables for individual *i* at time *t*, U_i is a set of unobservable factors for individual *i* that are not changing through time, hence the lack of the time subscript and ε_{it} is the error term. The fixed effect model removes the effect of time-invariant characteristics so we can assess the net effect of the predictors on the outcome variable.

Parallel trend

We tested the key assumption of DiD, i.e. the outcome in the treatment and control group would follow the same time trend in the absence of the treatment, i.e., a parallel trend would have existed between the two groups (Angrist and Pischke 2009). One way is the visual inspection of the trend (Fig 1.) for the treated and control groups for the pre-treatment period. A second way is to perform a 'falsification test or placebo test'. We performed a falsification test to estimate the DiD using the same treated and control districts used

Table 2 Unit root test for stationarity in data

Variables	Levin-Lin-Chu test			Harris-Tzavalis test	
	Unadjusted t	Adjusted t	p-value	Rho	p-value
	H_0: Panels contain Unit Root H_1: Panels are Stationary			H_0: Panels contain Unit Root H_1: Panels are Stationary	
Annual rainfall	-14.06	-4.47	0.00	0.14	0.00
CaIrri	-10.56	-2.04	0.02	0.51	0.00
TbIrri	-10.92	-2.42	0.00	-0.07	0.00
Population density	-12.21	-4.27	0.00	0.52	0.00
Crop diversification index	-11.89	-3.01	0.00	0.28	0.00
Annual water levels	-9.61	-1.91	0.02	0.69	0.75

Notes CaIrri = Ratio of Canal irrigated area to total irrigated area, TbIrri = Ratio of Tube well irrigated to total irrigated area

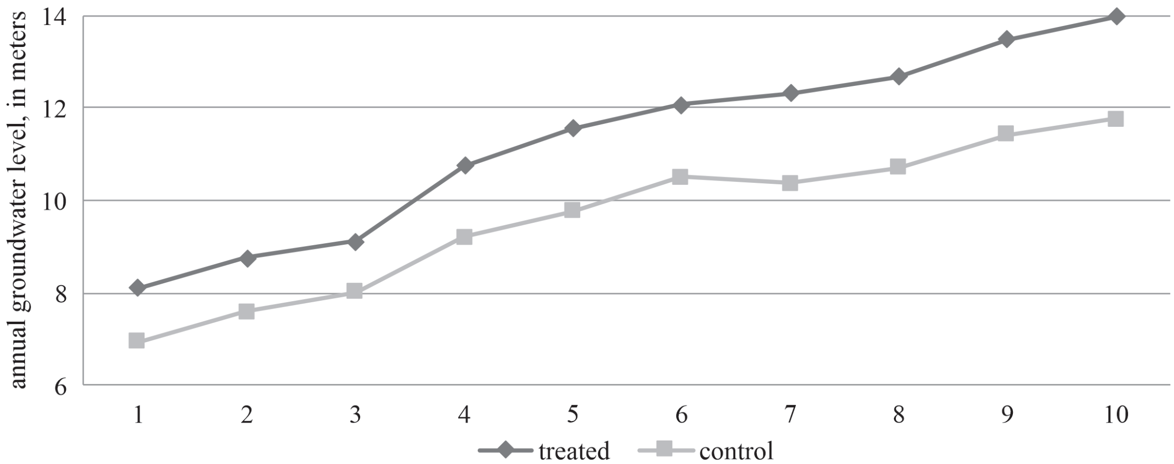

Figure 1 Parallel trend of annual groundwater levels for treated and control districts

in the previous regression for the pre-Act period. The modified version of the DiD model is:

$Y_{it} = \beta_0 + \beta_1$ Time + β_2 Tr + β_3 Time * Tr + ε_{it} …(4)

Where β_3 is the placebo interaction term from 1999 to 2008. The interaction term coefficient was statistically not significant, satisfying the parallel trend assumption.

Crop diversification index (CDI)

We measured the extent of crop diversification using the Herfindahl-Hirschman Index (HHI).

$$HHI = \left(\frac{Area_i}{Total\ Cropped\ Area}\right)$$

Where $Area_i$ is the area under 'i^{th}' crop. The value of HHI varies from zero (for perfect diversification) to one (for complete specialization). However, this concentration index cannot assume a theoretical minimum value for a finite number of crops. Also, it gives relatively more weight to larger crop activity (De and Pal 2017). The crop diversification index is defined as:

CDI = 1-HHI

Results and discussion

The shift of area under different water table depths

The area under critical water table depths has increased in Punjab. Figure 2 depicts the area under different water table depths within the state. The area under the water table depth of <10 m is considered non-critical

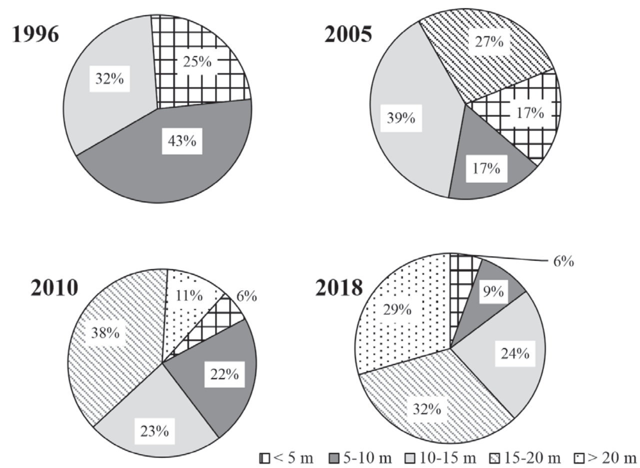

Figure 2 Change in water table depth, Punjab, 1996 to 2018

Source CGWB (2017) and Statistical Abstract of Punjab (various issues)

as the water could be lifted through centrifugal pumps. A depth of more than 10 m is considered critical for groundwater resources sustainability. The area under the non-critical stage has decreased while it has increased in the critical stage. The critical area in the state was around 32% in 1996, which rose to 85% in 2018.

A significant part of the irrigated area has shifted to deeper water table depths (Fig. 2), signifying that the state faces a sharp decline in groundwater resources. One of the reasons is intensive rice-wheat crop rotation practised in the state and decreased rainfall (Aggarwal et al. 2009). Even the non-critical area lies in those parts of the state where either the extraction is limited due to its brackish water (Muktsar, Bathinda, Mansa, i.e. south-west zone[1]) or the extraction is economically unviable due to rocky terrain (Hoshiarpur, SAS Nagar, Rupnagar, i.e. Kandi zone).

Stage of groundwater development

The annual groundwater recharge for the state increased 1.5 times, from 17 billion cubic metres (bcm) in 1984 to 23.93 bcm in 2017, while the annual draft increased 2.5 times from 14 bcm to 34.05 bcm resulting in a negative groundwater balance of 10.63 bcm (GOP 2017). The current stage of groundwater development is 166%. The draft as a percentage of recharge increased from 72 in 1984 to 98 in 1997 and further to 166 in 2017. All the districts of the Central zone are over-exploited, the stage of groundwater development is above 100 %. The state of groundwater development exceeded 200 % in most of the districts of the Central zone. The only two districts, Muktsar and Bathinda have 74% and 98% groundwater development, respectively. Bestowed at the time of the Green Revolution the boon of nature reversed in the later years due to the extreme utilization of water, soil, pesticides, and fertilizers (NABARD 2019). The block-wise map of groundwater assessed units reveals that out of the total 138 blocks in Punjab, 109 blocks are over-exploited, two are in critical, and five are in the semi-critical stage (Fig. 3). The increase in the number of over-exploited blocks (Shah et al. 2008; Kaur, Sidhu, and Vatta 2010; Kaur, Vatta, and Sidhu 2015; Kumar and Kaur 2019; Bhardwaj and Kaur 2019) is the result of indiscriminate extraction of groundwater for agricultural, industrial and domestic uses. The state's limited surface water supply and its reduction over time coupled with increased irrigation demand have strained groundwater resources (Singh et al. 2019). There is an immediate need to recharge groundwater in the over-exploited blocks and improve the available shallow groundwater in the safe blocks to prevent waterlogging soon.

Year to year fall of the water table

The June-over-June fluctuations in water level ranged between -0.11 to +0.93 metres with a cumulative fall

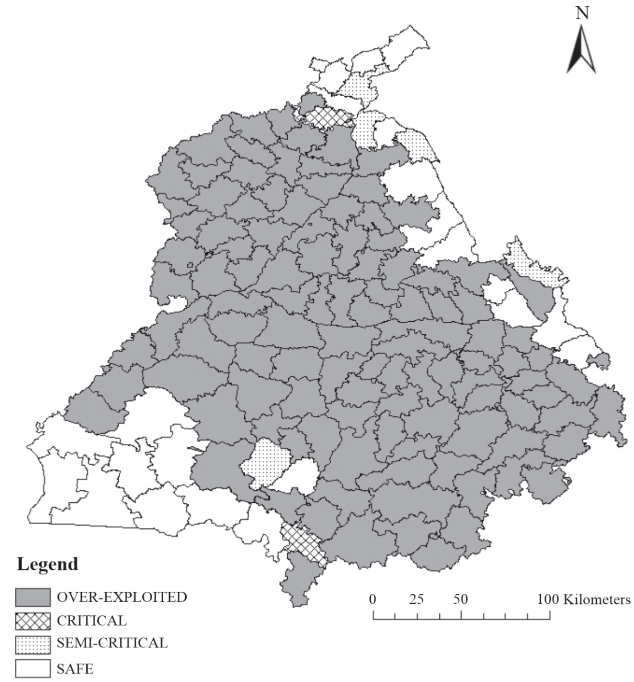

Figure 3 Categorization of developmental blocks, Punjab-2017
Source CGWB, 2017

of more than 8 metres (Table 3). The cumulative fall of 9.5 metres in the water table was observed for October-over-October. The impact of net monsoon recharge was captured through June-to-October water level fluctuations. The net monsoon recharge decreased 1 metre in 1996 to -1.11 metres in 2018. Since 2012, a greater fall in the water table in the monsoon months indicates less recharge as the water table goes deep and more stress on groundwater for withdrawal. The change through October-to-June depicts the effect of withdrawals in the rabi season. The withdrawals during the rabi season affect the monsoon recharge. The change in water level during October to June shows a fall from 0.31 metres to -0.26 metres during 1996-2018.

Surprisingly, central Punjab witnessed a greater water table fall than the southwestern and Kandi parts. The rate of fall in water-table (June-over-June) in central Punjab doubled after the first 12 years from 1974 and more than tripled during the next twelve years. The current fall has been arrested in the last eight years, although the figure reached 70.4 cms. The October-

[1]Kandi zone includes Gurdaspur, Hoshiarpur, SAS Nagar, Rupnagar, SBS Nagar and Pathankot; Central zone includes Ludhiana, Sagrur, Barnala, Moga, Jalandhar, Patiala, F. Sahib, Tarn Taran, Amritsar and Kapurthala while Southwest zone includes Bathinda, Mansa, Faridkot, Ferozepur, Fazilka and Muktsar.

Table 3 Year-to-year fall of the water table in Punjab

Year	June-over-June (m)	Cumulative fall June-over-June (m)	Oct-over-Oct (m)	Cumulative fall Oct-over-Oct (m)	June-to-Oct (m)	Oct-to-June (m)	Total water depletion (km^3)	Annual Average Rainfall (mm)
1996	—	-	—	-	0.61	-		607.4
1997	0.30	0.30	0.32	0.32	0.63	0.31	-3.02	708.7
1998	0.59	0.89	0.07	0.39	0.11	0.04	-5.94	477.4
1999	0.10	0.99	-0.62	-0.23	-0.61	0.01	-1.01	390.9
2000	-0.76	0.23	-0.38	-0.61	-0.23	0.15	7.65	391.9
2001	-0.28	-0.05	-0.53	-1.14	-0.48	0.05	2.82	462.8
2002	-1.00	-1.05	-1.19	-2.33	-0.67	0.52	10.07	314.5
2003	-0.47	-1.52	-0.13	-2.46	-0.33	-0.20	4.73	459.5
2004	-0.79	-2.31	-1.06	-3.52	-0.6	0.46	7.95	375.2
2005	-0.17	-2.48	0.50	-3.02	0.07	-0.43	1.71	565.9
2006	-0.15	-2.63	-0.09	-3.11	0.13	0.22	1.51	418.3
2007	-0.11	-2.74	-1.42	-4.53	-1.18	0.24	1.11	438
2008	-0.91	-3.65	0.37	-4.16	0.1	-0.27	9.16	529.2
2009	-0.22	-3.87	-0.69	-4.85	-0.37	0.32	2.21	384.9
2010	-0.40	-4.27	0.22	-4.63	0.25	0.03	4.02	472.1
2011	-0.11	-4.38	0.33	-4.3	0.69	0.36	1.10	218.9
2012	0.93	-3.45	-2.42	-6.72	-2.66	-0.24	-9.36	345.5
2013	-2.31	-5.76	0.36	-6.36	0.01	-0.35	13.19	619.7
2014	0.66	-5.1	-0.87	-7.23	-1.52	-0.65	-6.64	384.9
2015	-0.61	-5.71	-0.25	-7.48	-1.16	-0.91	6.14	546.9
2016	-0.16	-5.87	-1.39	-8.87	-2.39	-1.00	1.61	426.7
2017	-1.43	-7.30	-0.09	-8.96	-1.05	-0.96	14.40	493
2018	-0.79	-8.09	-0.85	-9.81	-1.11	-0.26	7.95	598.3

over-October analysis shows that groundwater table, which went down by less than 10 cms per year up to 1985 increased to about 20 cms during the period 1986-97 and became very serious thereafter, the average fall per year is nearly four times during 1998-2009 and almost 4.5 times during 2010-18 compared with the period of 1986-97 (Table 4).

However, the more fall in October-over-October signifies less rise in water level due to monsoon recharge and consequent fall in the groundwater table. This decline might be due to multiple factors such as an increase in area under paddy, an increase in the number of electricity-operated wells and a decrease in rainfall.

Table 4 Average per year fall in groundwater level in central Punjab

(cms)

Period	Average per year fall in groundwater level in cms	
	June-over-June	Oct-over-Oct
1974-85	9.4	8.4
1986-97	20.3	18.4
1998-09	62.5	75.5
2010-18	70.4	82.3

Source Singh, 2007 and Authors' calculation

Erratic monsoon and post-monsoon rainfall

We examined the % increase in rice area, the number of electricity operated tube-wells, electric tube well density and groundwater levels to strengthen our view that these multiple factors can be attributed to the area's groundwater regime.

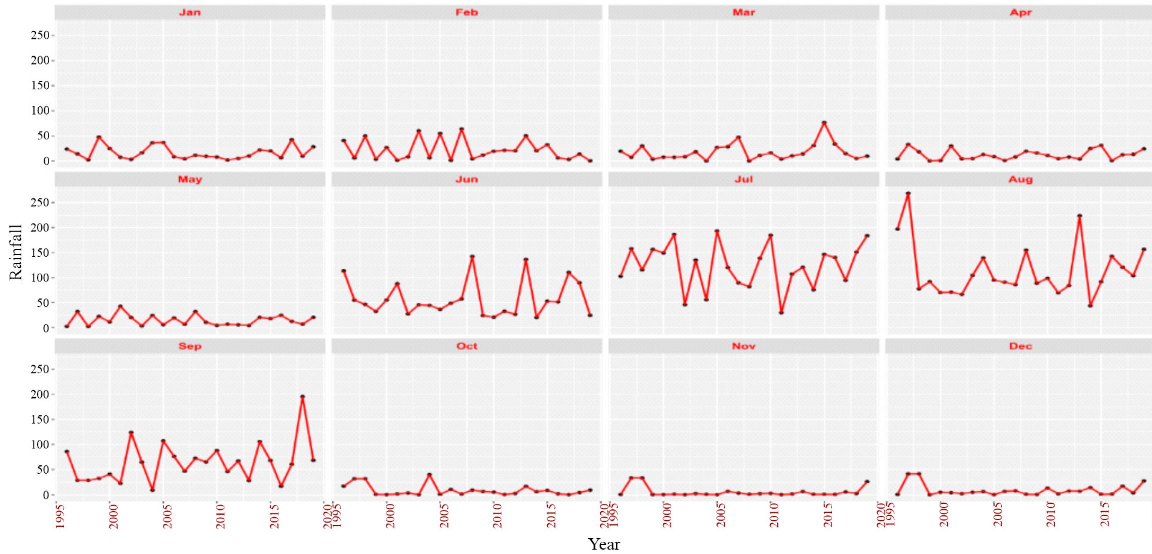

Figure 4 Monthly rainfall in Punjab
Source Statistical Abstract of Punjab (various issues)

Firstly, we studied the rainfall pattern over the period 1996 to 2019. It was observed that spatial variations in precipitation have occurred, with some years receiving more than average rainfall and some years receiving deficit rainfall (Fig. 4). October to May months depict low rainfall from 1995 to 2020. We have shown the annual rainfall pattern in Fig 5, which portrayed a more declining trend after implementing the Act, 2009.

The monthly and annual behaviour of rainfall shows that over-time decline in its quantity had an adverse effect on groundwater. Over the years, the decreasing rainfall has adversely affected the flow of water in major rivers and the natural recharge of groundwater resources. The inadequate amount of canal water for irrigation and groundwater use in excess of recharge has led to over-exploitation of groundwater resources

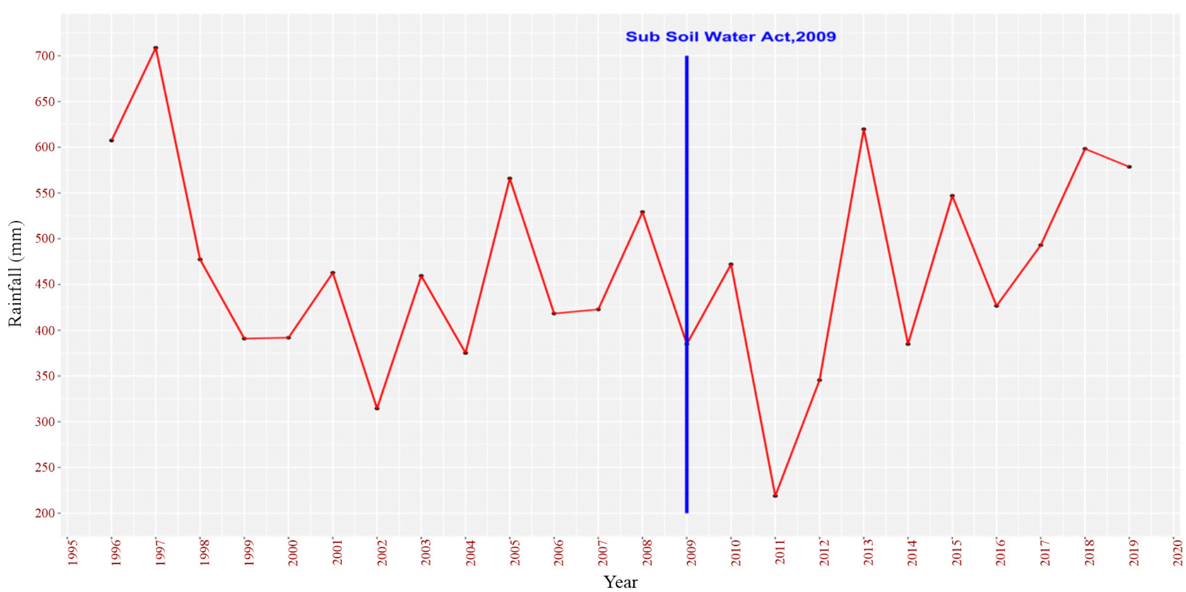

Figure 5: Annual rainfall pattern for the year 1999 to 2018
Source Indian Meteorological Department

Table 5 % increase in rice area and electric tube well density in Punjab

Particulars	1999	2008	% increase	2009	2018	% increase
Rice area (‘000 hectares)	2543	2639	3.77	2762	3095	12.05
Number of electricity-operated tube-wells (Lakhs)	7.59	9.81	29.16	10.33	13.66	32.30
Electric tube-well density (‘000 ha of NSA)	3555	4676	31.54	4916	6769	37.68

Source Statistical Abstract of Punjab (various issues)

in the state. Additionally, the rice area post the Act showed an increase of 12% (Table 5).

The number of electricity-operated tube-wells in 1999 was 7.59 lakhs which rose to 9.81 lakhs in 2008, increasing 29%. The increase in the post-Act period was 32%. The density of the tube-wells also showed a similar trend.

We studied the water table behaviour (shown in figure 6) pre and post the Act; it depicts a fall of more than 2 m pre-Act and more than 4 m post-Act. The groundwater level during June, which was 8.1 m in 1999, went down to 13.6 m in 2009 and further to 18.4 m in 2018.

We also studied the average decline in the water table during pre- and post-Act, which revealed that the groundwater level declined at an annual rate of 0.36 m from 1999-2009 (pre-Act) to 0.46 m per year during 2009-2018 (post-Act). A pictorial representation of the same is shown in Figure 7. This critical scenario of overexploitation brings forth the fact overtime decline in rainfall have put massive pressure on groundwater resources due to increased demand for water on account of water-intensive rice-wheat crop rotation.

Impact of ‘The Punjab Preservation of Sub Soil Water Act, 2009’

The results of DiD are presented in Table 6. The outcome variable is groundwater depth in mbgl (metres below groundwater level). The sign of the coefficient of the interaction term (Act*Tr) is interpreted opposite as water level is measured below the ground. Therefore, a positive coefficient of Act*Tr would be interpreted as falling groundwater depth. The effect of the Act, 2009 on annual groundwater levels has been shown in figure 7.

We used DiD approach to find the coefficient value of the parameter in two ways. The first specification of the DID model estimates the coefficient of an interaction term with district and year fixed effects. The second specification estimates the coefficient of

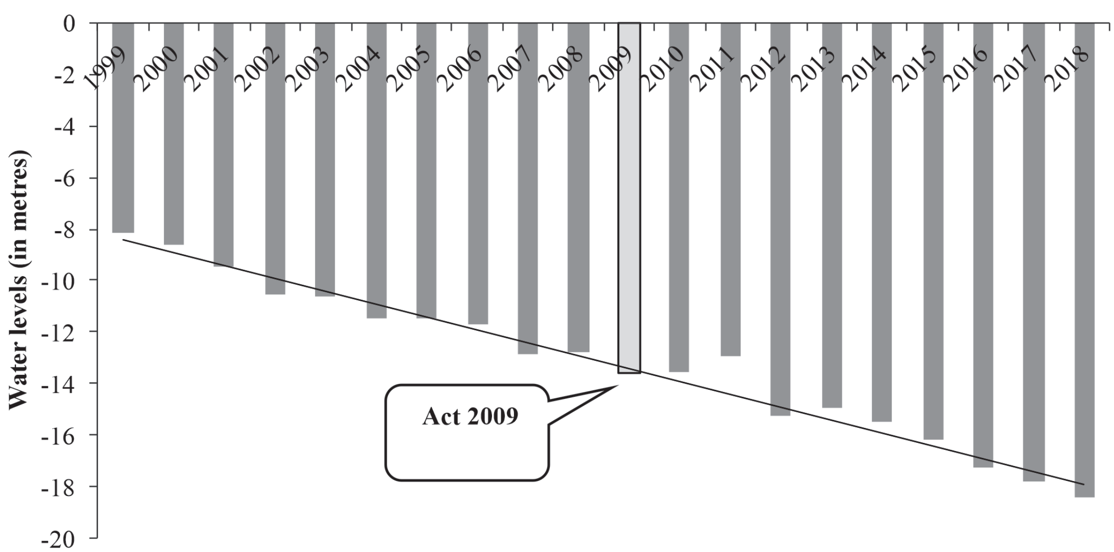

Figure 6 Groundwater levels in Punjab, pre-Act (1999-2008) and post Act (2009-2018)

Source CGWB: https://indiawris.gov.in/wris/#/groundWater

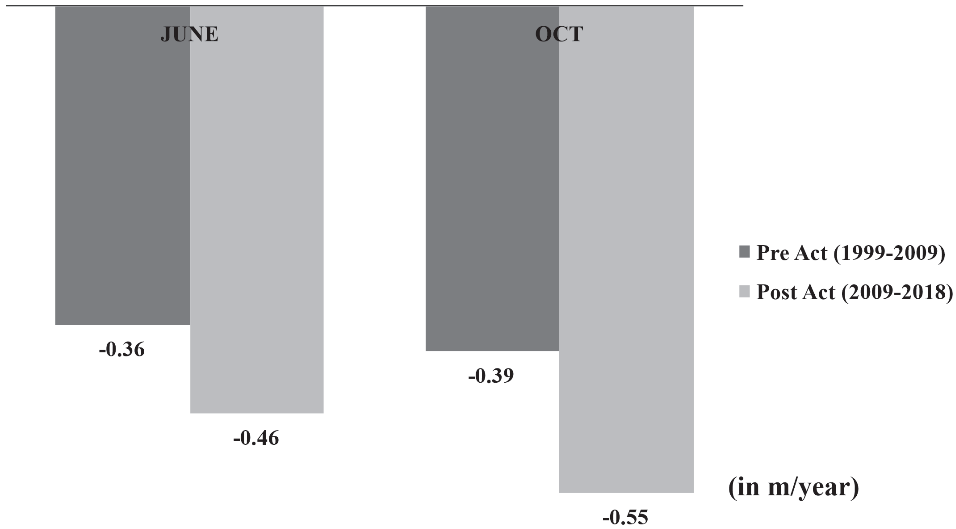

Figure 7 Average decline in the water table in Punjab, Pre and Post Act

an interaction term with all time-varying covariates like the ratio of canal irrigated area to total irrigated area, ratio of tube-well irrigated area to total irrigated area, population density and crop diversification index along with district and year fixed effects. In column (1) only the district and year fixed effects are added to the empirical model. All other covariates are added to the model in column (2).

Even after implementing the Act, 2009, the groundwater depth has fallen in the treated districts (high rice-growing). In both the specifications, the coefficient of the interaction term(Act*Tr) is highly significant and positive, indicating a decline in water level depth of nearly one and a half metres in treated districts. The groundwater depth in the high rice-growing districts was 1.62 mbgl deeper than in the low rice-growing districts after enacting the Act, 2009. Controlling demographic characteristics and other related variables such as irrigated area, canal availability, cropping pattern and rainfall reduces the fall in groundwater to 0.14 mbgl, clearly depicting the effect of these on the groundwater regime of the region. Overall, the groundwater levels fell more after the policy change in the high rice-growing, i.e. treated districts.

The increased paddy area, increased number of tube-wells, and replacement of centrifugal pumps into high HP submersible pumps would have resulted in a greater fall in groundwater in the absence of the Act, 2009. Undoubtedly, this Act, 2009 has created a gradual change in people's attitude toward groundwater conservation or awareness about the implications of water depletion. Otherwise, the rate of fall would have been even more, which got arrested due to this act. Some evidence shows that this regulation has arrested the rate of groundwater depletion. Tripathi, Mishra, and Verma (2016), using time series data from 1985 to 2011, found an annual rise of 0.2 cm in the groundwater

Table 6 Impact of 'The Punjab Preservation of Sub Soil Water Act, 2009' on annual groundwater levels

	Coefficient value (1)	Coefficient value(2)
Act*Tr	1.62*** (0.43)	1.48*** (0.44)
Annual rain(Rain)	No	Yes
The ratio of canal irrigated area to the total irrigated area(CaIrri)	No	Yes
The ratio of tube well irrigated area to the total irrigated area (TbIrri)	No	Yes
Crop diversification index(Cdi)	No	Yes
Population density(Pd)	No	Yes
District fixed effects(D_i)	Yes	Yes
Time fixed effects(T_t)	Yes	Yes
Observations	400	400
R^2	0.70	0.71

Note *** indicate significance at 1% probability level. Figures in parentheses are standard errors.

table after implementation of the Act, despite an increase in the area under paddy cultivation (Vatta et al. 2018). Singh (2009) estimated a potential increase of 30 cm in water level on implementing the Act. But, both these studies do not account for selection issues. However, Sekhri (2012) reports that the policy reforms in Punjab and Haryana, where delayed transplanting of paddy Act passed, had not impacted it positively.

Conclusions and policy implications

The agricultural sector in Punjab is currently in a crisis, with natural resources depleting, yields stagnating, and farm incomes declining. The continuous reliance on wheat and rice cultivation and an over-reliance on groundwater resources have prompted concerns about Punjab's agricultural sustainability. The available surface water is incapable of satisfying agricultural demand; as such, the groundwater is under increasing pressure. Punjab's depleting water table is a cause of grave concern as it has caused water quality problems in Punjab. The present study results revealed that the annual groundwater levels for the treated districts, after the Act, lowered by 1.48 metres as compared to the control districts. The groundwater in Punjab is falling with an average annual fall of 0.47 m. On the other hand, the soils of Punjab are still healthy and can continue to produce a variety of crops if the mono-cropping cycle of rice-wheat can be interrupted. The judicious use and conservation of water resources should be given top priority. A "Water Resources Regulatory Authority" should be established to encourage and regulate the optimum use of ground and surface water. In the state's Central region, special attention needs to be paid to the diminishing water tables. So, effective implementation of this Act requires that it be decentralized in nature. Engagement of the stakeholders (especially end-users) is an essential element for these policies to work. Shifting the date of paddy transplantation to the last week of June or the first week of July may not be a promising solution to halt the declining groundwater levels. Instead, adding new crops in cropping patterns and water use restrictions and placing the maximum limit on the cultivation of water-intensive crops can be adopted. Suitable risk management tools, such as insurance coverage or price support for potentially feasible alternative agricultural systems, must be implemented to encourage farmers to make the changeover.

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An assessment of India's virtual water trade in major food products

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Abstract This paper analyzes virtual water trade flows through food products between India and its trading partners. It relies on the gravity model of trade and estimates a panel data fixed effect regression to identify drivers of virtual water trade. Our results show that India was the net exporter of virtual water in food products during 1990-2013; however later it turned out to be its net importer. Further our analysis shows distance between trading partners as the primary driver of virtual water trade. India prefers trading with its neighbours to reduce transportation costs. The availability of arable land and water used in crop production are limiting factors for production of food crops and thus act as essential factors in deciding the virtual water trade flows. These findings indicate that resource endowment factors influence bilateral virtual water trade flows.

Keywords Fixed effects regression, Food crops, Gravity model, Virtual water trade

JEL Codes F14, Q17, Q25

Production agriculture requires water, and the water embedded in the final product is called virtual water (Allan, 1993). The same concept is referred to as 'embedded water' (Allan, 2003) and 'water footprint' (Mekonnen and Hoekstra 2011). Mekonnen and Hoekstra (2011, 2011a, 2012) provide a detailed country-wise water footprints of crops, derived crop products, biofuels, livestock products, and industrial products.

When the final output with embedded water is traded in domestic and international markets, it is termed as a Virtual Water Trade (VWT). The quantity of global VWT during 1995-1999 was computed by Hoekstra and Hung (2002, 2005) for crops, and by Chapagain and Hoekstra (2003) for livestock and livestock products. Mekonnen and Hoekstra (2012a) assessed the global VWT for crops, livestock, and industrial products during 1996 - 2005.

Applying the idea of VWT in the context of water-saving, the import of water-intensive products leads to saving of water. It lessens the burden on the country's scarce water resources. However, it is necessary to exchange agricultural products to ensure nation's food security. Hence, there is always a trade-off between food security and water-saving through trade. Agriculture is one of the sectors which intensively uses water. With highly uneven rainfall and frequent departures from normality, water scarcity has become a significant concern in India which is expected to be exacerbated by climate change. It will affect the livelihoods of millions of farmers (Rodell et al. 2018). The situation is further aggravated as the marginal and small landholdings dominate Indian agriculture with inadequate adaptive capacity. Hence, improving water use efficiency along with developing efficient water management practices are important.

The concept of virtual water trade is crucial to understand water management strategies to utilize available water resources through trading agricultural commodities. In the agriculture sector, the extent of virtual water trade varies widely across countries and food products. Such differences in the quantity of virtual water trade arise due to various factors. Hence, examining the drivers of virtual water trade will help formulate well-informed regulations on export and import of food products. With this background, this paper focuses on estimating virtual water trade and its determinants.

Materials and methods

Estimation of India's net virtual water trade for crops

Crop-specific virtual water content (VWC) is the basis for estimating the extent of net virtual water trade in food products between India and its trading partners. We relied on virtual water content estimates given by Mekonnen and Hoekstra (2010). We followed the computation method given by Yang et al. (2006) to assess the extent of virtual water export and import. In 2017, India exported 52 crop products and imported 50 crop products (Appendix 1). All these products were considered to assess the magnitude of the virtual water trade. The time series data (1990-2017) on quantities of food products exported and imported by India was extracted from the FAOSTAT.

The gross volume of virtual water export (GVWE) from India is estimates as

$$GVWE_{tij} = \Sigma\,(Crop\ Product\ Exports_{pt} * VWC_{pi})$$

The gross volume of virtual water import (GVWI) to India is estimated as

$$GVWI_{tij} = \Sigma\,(Crop\ Product\ Imports_{pt} * VWC_{pi})$$

Where i is an exporting country, j is an importing country, p is a crop product, t is time, and VWC is virtual water content.

Net virtual water trade (NVWT) is given by

$$NVWT_{tij} = GVWI_{tij} - GVWE_{tij}$$

The gravity model of trade: variables, data, and empirical specification

The gravity model explains trade flows between trading partners, and resembles the universal law of gravitation (Bergstrand 1985).

$$F_{ij} = \beta_0 \frac{v_i v_j}{d_{ij}^2}$$

Where, F_{ij} is the trade between countries i and j. v_i and v_j are values of the relevant variable for the country i and j, and d is the distance between the countries. A general specification of the gravity model of trade used by Head and Mayer (2014) includes a broader variety of determinants of bilateral trade, and can be written as

$$X_{ij} = GS_i{}^{\alpha} S_j{}^{\beta} Y_{ij}{}^{\gamma}$$

$$X_{ij} = GS_i^{\alpha} S_j^{\beta} Y_{ij}^{\gamma}$$

The gravity model of trade is a model of bilateral trade interactions in which size and distance effects enter multiplicatively, where S_i represents all the features that affect the exporter i as all partners, S_j captures all features of j as a destination market from all sources, and Y_{ij} is a measure of the accessibility of market j for the producers of country i, and it subsumes any other pair-specific factor influencing bilateral trade. The multiplicative expression of the gravity equation can be estimated more easily employing Ordinary Least Square (OLS) estimators after taking logs of the equation.

Above mentioned classical gravity model generally uses one time period data to estimate determinants of trade. However, the time trend in panel data captures the time fixed effects. Tamea et al. (2014) used 25 years of cross-sectional data to study the determinants of virtual water trade. The advantages of panel data are two-fold. It captures the relevant relationships among variables over time and looks for unobservable trading partner pairs' individual effects. Therefore, we used panel data for estimating the gravity model of the virtual water trade.

Given the multiple partner countries involved in a trading relationship, the panel data takes into account export or import of specific commodities with various countries over time. For the model describing virtual water import and virtual water export, we rely on the modified form of the model used by Tamea et al. (2014). Here, we look for two gravity laws for India: one describing the export as a function of the characteristics of destination countries, and another describing the import as a function of the characteristics of source countries.

Identifying the exporting country by *i* and the importing country by *j*, two different estimates are given for the virtual water trade from country *i* to country *j* as follows:

$$VWE_{ij} = \beta_0 (gdppc_j)^{\beta_{1j}} (pop_j)^{\beta_{2j}} (D_{ji})^{\beta_{3j}} (pcl_j)^{\beta_{4j}} (vwp_j)^{\beta_{5j}}, \quad j \in \Omega_d(i) \qquad \ldots(1)$$

$$VWI_{ij} = b0 (gdppc_i)^{b1i} (pop_i)^{b2j} (D_{ji})^{b3i} (pcl_i)^{b4i} (vwp_i)^{b5i}, \quad i \in \Omega_d(j) \qquad \ldots(2)$$

Where, *VWE* is a virtual water export, *VWI* is a virtual water import, *gdppc* is the gross domestic product per capita, *pop* is population, *D* is the distance between India and the trading partner, *pcl* is per capita availability of arable land, and *vwp* is virtual water used in the production of corresponding crops.

Equation (1) expresses the demand's pull for export, describing the virtual water export as a function of destination characteristics, referred to as the export law. Similarly, Eq.(2) expresses the supply's push for import, describing the virtual water import as a function of source characteristics, referred to as the import law (Tamea et al. 2014).

The dependent variable is the total amount of water embodied in the food products exchanged between India and partner countries (i.e, virtual water export / virtual water import). To obtain the VWE and VWI estimates of country-specific virtual water content (CVWC) for various crop products provided by Mekonnen and Hoekstra (2010) are multiplied by the quantity of exchanged food products registered in the international trade data from the FAOSTAT database.

$$VWE_{pijt} = Export\ quantity_{pijt} * CVWC_{pi}$$

$$VWI_{pijt} = Import\ quantity_{pijt} * CVWC_{pj}$$

Among the independent variables of the virtual water trade, the foremost to be used are variables measuring the economic mass of the countries, i.e., population (pop), GDP per capita (gdppc) and the geographical distance (D) i.e., the average physical distance between the most populated cities of any pair of countries given by CEPII (*http://www.cepii.fr/anglaisgraph/bdd/distances.htm*), as in Tamea et al. (2014).

The resources used in agricultural production are other potential factors driving virtual water trade. The measure of the availability of land for cultivation, i.e., per capita availability of arable land (pcl) and virtual water used in crop production (vwp) are other determinants of export or import of agricultural products. The time series data (1990-2017) on availability of arable land and water in India's trade partner countries were extracted from the FAOSTAT.

Virtual water used for crop production (VWP_c) is calculated by multiplying country-specific virtual water content (CVWC) of crops (Mekonnen and Hoekstra, 2010) with the quantity of crop production:

$$VWP_{cit} = Production_{cit} * CVWC_{ci}$$

$$VWP_{cjt} = Production_{cjt} * CVWC_{cj}$$

Both dependent and independent variables are converted into logarithm of base 10. So, identifying the exporting country by *i*, importing country by *j*, for crop products *p*, crops *c*, for time *t*, the following model is proposed for gravity model.

The gravity model of export is:

$$ln\ (VWE_{ijpt}) = \beta_0 + \beta_{1j} ln(gdppc_{jt}) + \beta_{2j} ln(pop_{jt}) + \beta_{3j} ln(D_{ij}) + \beta_{4j} ln(pcl_{jt}) + \beta_{5j} ln(vwp_{cjt}) + e_{ijct} \qquad \ldots(3)$$

The gravity model of import is:

$$ln\ (VWI_{ijpt}) = \beta_0 + \beta_{1i} ln(gdppc_{it}) + \beta_{2i} ln(pop_{it}) + \beta_{3i} ln(D_{ij}) + \beta_{4i} ln(pcl_{it}) + \beta_{5i} ln(vwp_{cit}) + e_{ijct} \qquad \ldots(4)$$

Method of estimation of the gravity model

Gravity model involving panel data intended to examine heterogeneity or individual effect that may or may not be observed. If the heterogeneity effect does not exist in data, ordinary least squares (OLS) produce efficient and consistent parameter estimates. However, as Head and Mayer (2014) pointed out the pooled OLS for panel data estimates may no longer be the best unbiased linear estimator due to individual effect not being zero in panel data. This heterogeneity leads to disturbances that vary across individuals (heteroskedastic) and/or are related to each other (autocorrelation).

To examine the heterogeneity effect, the fixed effect panel data model is valid. A fixed effect model examines group differences in intercepts. The "within" estimation method of fixed effect panel data regression does not need to create dummy variables. It thus has large degrees of freedom, smaller Mean Squared Error (MSE) and smaller standard errors of parameters than those of the least squares dummy variable (LSDV) method. Also, Fracasso (2014) argues that the fixed effect model sufficiently captures the heterogeneity effect, thereby warning against pooling (pooled OLS) all the entities. Also, Fracasso argued that adopting gravity equations for panel data, as done by Tamea et al. (2014), is a more appropriate approach. In addition, robust standard errors are used to obtain unbiased standard errors of coefficients under heteroscedasticity.

After incorporating time fixed effect in the model, the gravity model of export is:

$$ln\ (VWE_{ijpt}) = \beta_0 + \beta_{1j}ln(gdppc_{jt}) + \beta_{2j}ln(pop_{jt}) + \beta_{3j}ln(D_{ij}) + \beta_{4j}ln(pcl_{jt}) + \beta_{5j}ln(vwp_{cjt}) + \rho_j + e_{ijct} \quad \ldots(5)$$

And, the gravity model of import is:

$$ln\ (VWI_{ijpt}) = \beta_0 + \beta_{1i}ln(gdppc_{it}) + \beta_{2i}ln(pop_{it}) + \beta_{3i}ln(D_{ij}) + \beta_{4i}ln(pcl_{it}) + \beta_{5i}ln(vwp_{cit}) + \rho_i + e_{ijct} \quad \ldots(6)$$

where, ρ_j and ρ_i are the time fixed effect coefficients for importing countries and exporting countries, respectively.

We prepared a panel dataset for the top 3 commodities (crop products) of exports and imports in terms of virtual water content to conduct the empirical analysis. The time fixed effect within the estimation regression method was applied for each commodity separately. Crop products selected for virtual water export (Table 1) are milled rice, refined sugar and groundnut shelled. These commodities contributed 68% of virtual water export from India in crops During the Triennium ending (TE) 2017. Similarly, commodities selected for virtual water import (Table 1) are palm oil, soybean oil and sunflower oil. These commodities contributed 61% of virtual water import in crops during TE 2017. All data are annual values for the years 1991 to 2017. The countries included in the estimation were chosen based on data availability so that there is no missing data for any variables. The exact number of countries and the total number of sample used for analysis is given in Table 2.

Results and discussion

Net volume of the virtual water trade

Quantity of net virtual water trade (NVWT) in food crops shows that until 1998 India was the net exporter of virtual water in food products (Figure 1). However, during 1999-2013, we see a mix of net export and net import of virtual water in food crops. During 1999-2001, 2006, and 2009 India was the net importer of water in food crops. These results are in line with the findings of Hoekstra and Hung (2002) that during 1995-1999 India was a net exporter of virtual water. However, after 2013, India became the net importer of water in food crops. India's changing position from a net exporter to a net importer of virtual water from

Table 1 Crop products considered for virtual water export / import and corresponding crops considered for virtual water production

Virtual water export		Virtual water import	
Crops for VWP	Crop product for VWE	Crops for VWP	Crop product for VWI
Paddy	Milled rice	Soybean seed	Soybean oil
Groundnut	Groundnut shelled	Sunflower seed	Sunflower oil
Sugarcane	Refined sugar	Palm kernel	Palm oil

Note CVWC for crops and crop products are different

Table 2 Sample size and number of countries considered for analysis

Virtual water export			Virtual water import		
Crop product	No. of countries	Sample size	Crop product	No. of countries	Sample size
Milled Rice	98	1739	Soybean oil	22	189
Groundnut shelled	45	594	Sunflower oil	19	142
Refined sugar	43	560	Palm oil	9	94

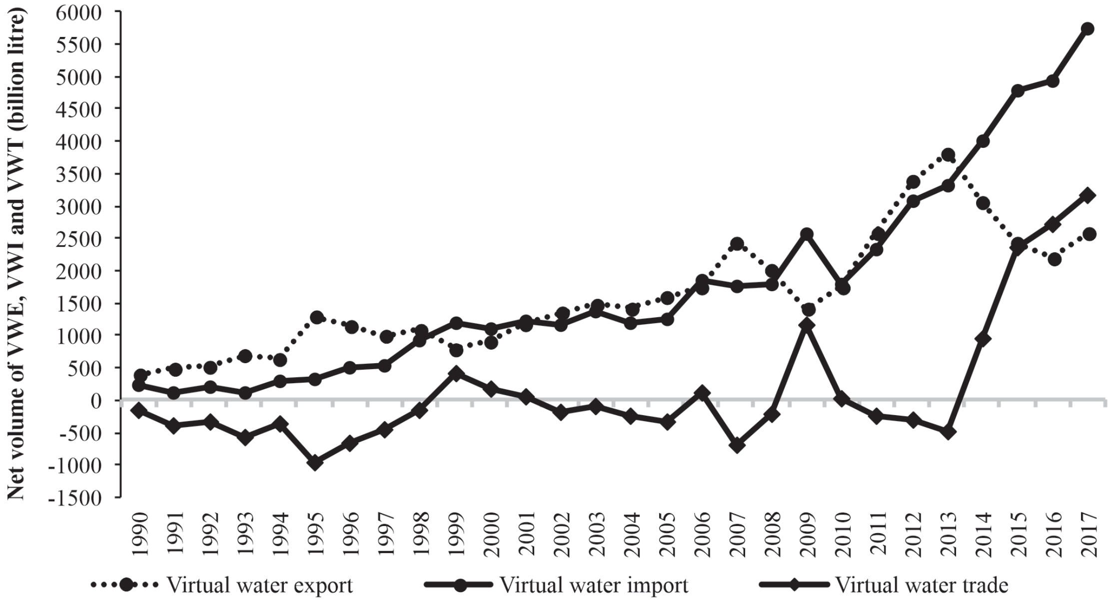

Figure 1 Net volume of virtual water trade of India

2014 to 2017 is due to changes in the composition of quantity exported and imported. There was a decline in the export of milled rice, soybean cake and wheat flour, which are water-intensive products. At the same time, there was a significant spike in the import of oil products especially, sunflower oil, soybean oil and oil palm.

Several studies have highlighted the role of global virtual water trade in water-saving and food security (Hoekstra and Hung 2002, Chapagain and Hoekstra 2003, De Fraiture et al. 2004, Mekonnen and Hoekstra 2012a). The water productivity differences between trading countries generate water savings (De Fraiture et al. 2004). Hence, the water deficit countries can gain through importing virtual water from water-surplus countries instead of producing water-intensive commodities locally. Oki and Kanae (2004) estimated that the global water saving from the virtual water trade was about 455 Giga cubic meters (Gm^3) per annum. Muratoglu (2020) showed that between 2008 and 2019, Turkey's annual water-saving through the virtual water trade was 7.8 Gm^3. The global virtual water deficit due to the wheat trade is 1.76 Gm^3/year. Alamri and Reed (2019) concluded that during 2000-2016, the virtual water trade reduced Saudi Arabia's water deficit by 54%. However, virtual water trade may also lead to water wastage when lower water productive countries export more virtual water to high water productive countries.

Drivers of virtual water export from India

A gravity model for the virtual water export of milled rice includes all the five variables that typically enter the model (Table 3). Both economic mass related variables viz per capita GDP and population of importing countries are found to have a significant positive association with virtual water export of milled rice from India. On the other hand, the average per capita availability of arable land in the importing country is negatively and significantly associated with the virtual water export of milled rice from India. Similarly, there is a significant inverse relationship between the volume of virtual water used in paddy production in importing countries and the virtual water export of milled rice. The distance between India and its trading partners is also a significant factor influencing the virtual water export. India tends to export more to its immediate neighbouring countries.

The virtual water export of refined sugar from India is positively related to importers' population. Therefore, it implies that India tends to export a higher quantity of refined sugar to populated economies. However, among other variables entered into the gravity model, per capita availability of arable land, the quantity of virtual water used in sugarcane production and distance between India and importing countries were found to have a significant negative influence on India's export of refined sugar.

Table 3 Drivers of virtual water export from India

Variables	Milled rice	Refined sugar	Groundnut Shelled
lngdppc	0.132**	-0.031	-0.308
	(0.053)	(0.048)	(0.264)
lnpop	0.512***	0.444***	0.642***
	(0.058)	(0.056)	(0.068)
lnpcl	-0.130**	-0.245*	-0.678***
	(0.053)	(0.137)	(0.065)
lnvwp	-0.068*	-0.242***	-0.102***
	(0.037)	(0.072)	(0.032)
lndist	-0.478***	-1.375***	-0.268***
	(0.109)	(0.164)	(0.086)
Constant	15.66***	22.56***	12.14***
	(0.987)	(1.399)	(1.989)
Observations	1,739	566	594
No. of years	28	28	28
F-stat	64.79***	49.33***	33.18***
R-squared	0.552	0.526	0.663

Note Robust standard errors in parentheses, Level of significance *** $p<0.01$, ** $p<0.05$, *$p<0.1$

Virtual water export of groundnut is more prominent when the trading countries are populated. On the other hand, India's virtual water export of groundnut shelled significantly decreases with a higher per capita availability of arable land in importing countries. Furthermore, the distance between India and importing partners is significant and negative, indicating that countries nearer to India import more groundnut shelled than distant countries.

Overall, the distance between India and importing countries, which is a proxy for transportation cost, is the primary driver for the virtual water export of the commodities under study. Virtual water used in agricultural production negatively influences virtual water export of selected food products. Whereas, per capita availability of arable land is negatively related to the virtual water export of all except wheat flour. Virtual water export is positively related to the population of importing countries for milled rice, refined sugar, and groundnut shelled. Per capita GDP is positively influencing the virtual water export of only milled rice and soybean cake. A similar study conducted by Kumar and Singh (2005) showed that the quantity of available land is one factor that limits the production of agricultural goods and thus virtual water exports.

Drivers of virtual water import to India

The gravity model for India's virtual water import of soybean oil, sunflower oil and palm oil showed that the per capita GDP is a significant driver of the import law (Table 4). The population of exporting countries had no significant influence on India's virtual water import. When source countries are considered under import law, an import flux is higher from the partner countries with more arable land. So, the per capita availability of arable land positively and significantly influences virtual water import in the case of soybean oil and sunflower oil, except palm oil. Virtual water used in producing these crops in exporting countries has a favourable influence on India's virtual water import, as higher production in source countries led to more products available for export. This effect was high in the case of palm oil. It is noted that Indonesia, Malaysia, the Philippines and Thailand are the four major palm oil-exporting countries to India. Among these, India imports more than 95% of palm oil from Indonesia and Malaysia. Both these significant oil palm producers are located in south-east Asia, reducing the

Table 4 Drivers of virtual water import to India

Variables	Soybean oil	Sunflower oil	Palm oil
lngdppc	2.028***	1.715**	0.593**
	(0.326)	(0.651)	(0.219)
lnpop	0.206	0.203	-0.246
	(0.281)	(0.287)	(0.251)
lnpcl	0.778**	1.288**	-0.536
	(0.353)	(0.596)	(0.502)
lnvwp	0.264**	0.708***	1.162***
	(0.124)	(0.217)	(0.088)
lndist	-1.177***	-1.822***	-0.962***
	(0.226)	(0.299)	(0.276)
Constant	1.369	0.443	-9.278
	(3.381)	(11.31)	(5.870)
Observations	189	142	94
No. of years	28	25	28
F-stat	54.86***	51.65***	100.81***
R-squared	0.516	0.614	0.867

Note Robust standard errors in parentheses, Level of significance *** $p<0.01$, ** $p<0.05$, *$p<0.1$

transportation cost involved in the import. The distance between India and exporting countries negatively influence India's virtual water import. It indicates that India tends to import edible oil from countries located nearby.

Overall, the per capita gross domestic product is a significant positive driver of virtual water fluxes, especially under import law. Tamea et al. (2014) confirmed that distance is the fundamental factor controlling virtual water flows for imports and exports. In the literature of gravity model, distance is used as a proxy for transportation costs. The negative sign for an estimated parameter indicates that countries prefer to import from neighbouring countries to reduce transportation costs.

In international trade, the concept of virtual water is used to optimize the trade of commodities by considering the endowment of water resources of the nations. In line with Heckscher Ohlin (HO) theorem, virtual water trade advocates that water-abundant countries may produce commodities that use more water and export the same to water-scarce countries. Thus, it enables water-scarce nations to utilize their water resources for high productive activities. The gravity model of trade is a well-known model to identify the factors influencing virtual water flows between countries. Debaere (2014) found water as a source of comparative advantage in line with the HO theorem. A similar relationship between scare water endowments and lower net virtual water exports was found by Yang *et al* (2003) and Kumar and Singh (2005).

Wichelns (2004) suggested that other factors such as production technologies, domestic and international goods prices, and trade barriers also significantly influence virtual water trade apart from water endowment. In contrast, Ramirez-Vallejo and Rogers (2004) found no association between virtual water trade and water resource endowment. Suweis et al. (2011) describe the gross domestic product (GDP) and rainfall as the significant factors responsible for virtual water trade. Tamea et al. (2014) found that the population, per capita GDP, and distance influence virtual water trade. Instead, average income, population, value-added agriculture, and irrigation coverage significantly influenced virtual water trade (Ramirez-Vallejo and Rogers 2004, Tamea et al. 2014). Land availability limits agricultural production and virtual water trade (Kumar and Singh 2005, Fracasso 2014, Head and Mayer 2014, Zhao et al. 2019).

Conclusions

This paper has assessed the magnitude and drivers of the virtual water trade of India in the crop sector. The assessment of net virtual water trade in crop products during 1990-2017 showed that India's position has changed from the net exporter of virtual water to the net importer during 2014-2017. We used a gravity model with a panel data regression method to examine the factors influencing virtual water export and import during 1991-2017. The results showed that the distance is the primary driver of virtual water trade in all selected crops. The availability of arable land and water used in crop production are limiting factors for the production of food crops and thus act as essential factors in deciding the virtual water trade flows. The resource endowment factor for virtual water import also confirms the HO model that goods intensive in factors (land and water) are exported by countries with relatively abundant endowments.

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Appendix 1 List of food Products Traded by India

Export Products (52)		Import Products (50)	
Rice, milled	Cake, groundnuts	Oil, palm	Cake, mustard
Cake, soybeans	Lentils	Flour, Wheat	Sugar refined
Sugar refined	Oil, sesame	Oil, soybean	Cake, soybeans
Rice, broken	Linseed	Peas, dry	Flour, wheat
Oil, castor beans	Sugar nes	Oil, sunflower	Rice, milled
Groundnuts, shelled	Sunflower seed	Chick peas	Groundnuts, shelled
Maize	Peas, dry	Lentils	Sunflower seed
Cake, rapeseed	Oil, sunflower	Beans, dry	Sugar nes
Sesame seed	Oil, soybean	Oil, rapeseed	Flour, maize
Soybeans	Cake, sunflower	Barley	Cake, linseed
Wheat	Buckwheat	Cake, sunflower	Mustard seed
Flour, wheat	Cake, sesame seed	Oil, palm kernel	Groundnuts, prepared
Sugar Raw Centrifugal	Barley	Maize	Buckwheat
Chickpeas	Cake, mustard	Soybeans	Linseed
Sugar confectionery	Oats rolled	Molasses	Flour, pulses
Molasses	Cake, linseed	Sesame seed	Oil, sesame
Millet	Oats	Oilseeds nes	Flour, cereals
Flour, maize	Oil, palm	Oats rolled	Cake, rapeseed
Beer of barley	Oil, linseed	Cake, palm kernel	Rice, broken
Groundnuts, prepared	Rapeseed	Oats	Millet
Flour, cereals	Oil, safflower	Malt	Cake, groundnuts
Sorghum	Oil, rapeseed	Sugar confectionery	Oil, castor beans
Mustard seed	Oil, palm kernel	Oil, safflower	Oil, groundnut
Flour, pulses	Oil, maize	Oil, linseed	Cake, sesame seed
Malt	Rye	Beer of barley	Oil, maize
Oil, groundnut	Maple sugar and syrups		

Source FAOSTAT

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Social vulnerability and adaptation to climate change: evidence from vulnerable farmers' groups in Odisha, India

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Abstract Farmers are the worst-affected and differentially vulnerable to climate change. This article has dealt with two research questions: (i) what factors drive the social vulnerability of farmers' groups to climate change?, and (ii) how they adapt to the negative effects of climate change? The study applied an indicator-index approach to measuring the social vulnerability of different categories of farmers. The findings reveal that the small and marginal farmers are more vulnerable to climatic risks than are the medium and large farmers possibly because of their weak economic and social conditions. In this context, adaptation is key to reducing the climatic impacts and building the resilience of the agricultural system.

Keywords Climate change, farm households, social vulnerability, coping

JEL Codes Q54,Q12,Q59

Human-induced climate change is unambiguously a global environmental phenomenon with far-reaching local implications (Stern 2006, IPCC 2007, IPCC 2014, Karl et al. 2009). Even though the developing countries contribute less to the stock of total annual carbon dioxide, they are the worst-affected and more vulnerable to climate change and its associated risks (Maskrey et al. 2007). In developing countries, resource-poor households who are largely dependent on agriculture are more affected by climatic risks (Maskrey et al. 2007). In this context, the World Bank's South Asia Climate Change Strategy Report indicates that the poorest people in South Asia suffer the most due to unfavourable geography, limited assets and increasing reliance on climate-sensitive income sources (World Bank 2009). The frequent occurrence of climate change-induced extreme events in the region exacerbates severe potential challenges to social, economic and ecological systems (Zhuang 2009, Mirza 2011) and these are expected to keep the poor perpetually stuck in a poverty trap (Mendelsohn and Diner 1999).

Odisha is the natural-disaster capital of India. The climate of Odisha is characterised by high temperature and high humidity. The state receives about 80% of the annual rainfall during the South-West monsoon (June-September) (Mishra and Mishra 2010), but its distribution is uneven over space. The Disaster Management Report, published by the Department of Agriculture, Odisha, highlights that "out of 52 years, only 13 years have shown the normal rainfall, therefore putting state with 75% probability of being visited by the natural calamity of any type". The erratic and inadequate rainfall often causes flood and drought situations and consequently triggers crop loss and low productivity of agriculture. Farmer suicides have been commonly prevalent across the state. Besides, Odisha being a coastal state is frequently visited by cyclones and super-cyclones.

Conceptual Framework of Social Vulnerability

Vulnerability is a fuzzy concept (Holand et al. 2011) varying in its meaning across disciplines. Among its

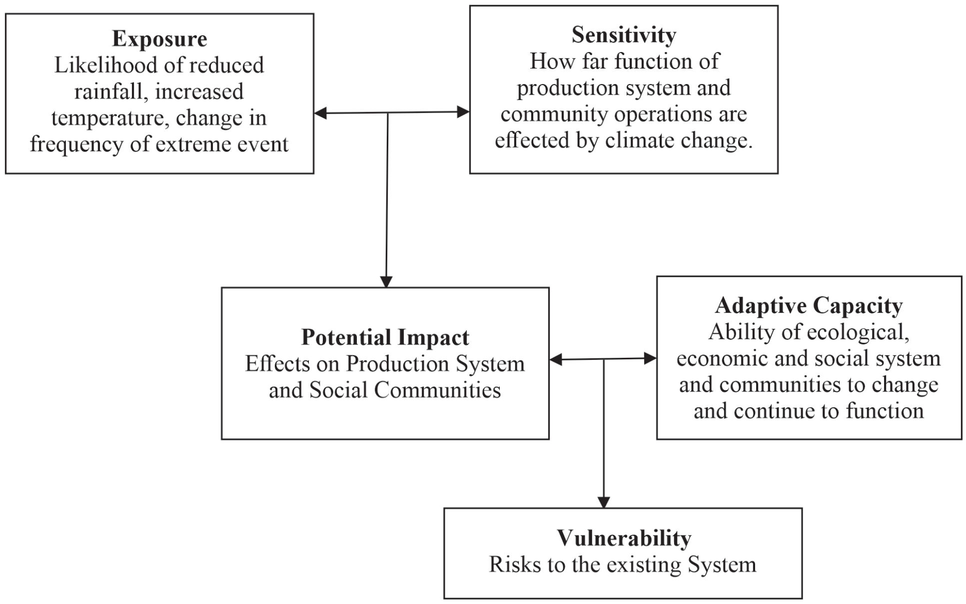

Figure 1 Important components of vulnerability
Source Jamshidi *et al.* (2018)

various definitions, the most comprehensive and accepted definition as given by the Third Assessment Report of Inter-governmental Panel on Climate Change (IPCC) (2001): "The degree to which a system is susceptible to or unable to cope with, adverse effects of climate change, including climatic variability and extremes. Vulnerability is a function of character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity." Hence, the vulnerability of any system is positively related to its exposure and sensitivity, and negatively related to its adaptive capacity. These components of vulnerability have been schematically represented in Figure 1. The notion of vulnerability is multi-dimensional[1] which varies across temporal and spatial scales, and is also differentiated among and within the social groups. It is scale-dependent regarding physical space and units of analysis – such as individuals, households, community, region or system. The characteristics, patterns and driving forces of vulnerability change over time (Vogel and O' Brien 2004, Cardona et al. 2012) and according to situations (Zimmermann 2017).

There are two existing epistemological traditions behind the understanding of the notion of vulnerability in climate change research (Brooks 2003): biophysical, and social. The definitions of vulnerability available in the climate change literature fall between these broad classifications. From the climate scientists' perspective, the "biophysical vulnerability" is understood in terms of the amount of potential damage or loss triggered to a system by a climate-related event or hazard (Jones and Boer 2003) in which the role of human systems in mediating the outcome of the hazard event is downplayed. It is particularly determined by the nature and frequency of physical hazards to which the system is exposed, the system's sensitivity to its impact and the extent of its human exposure (Brooks 2003). While, from the social scientists' perspective, "social vulnerability" is defined in terms of the existing structural and inherent characteristics of the affected human or societal system, independently of external hazards, that cause to amplify or reduce the damage. In this view, as argued by Blaikie et al. (1994) and Adger and Kelly (1999), social vulnerability is determined by the driving factors - poverty and inequality, marginalisation, food entitlements, access to insurance and housing quality. In this context, the political-economic approach to social vulnerability, as it is based on the theory of marginalisation (Susman et al., 1983) and the theory of food entitlements (Sen,

[1]The multi-dimensionality of vulnerability as a concept is broadly restricted to bio-physical and social dimensions for the sake of serving the arguments.

1981), emphasises the central importance of differential political and economic powers which determines the differential vulnerability of individuals and groups (Greenberg et al. 1994). Moreover, the broadened view of social vulnerability, in this formulation, underlies the interaction of hazards with a social vulnerability which influences the outcome, as measured in terms of physical or economic damage and human morbidity or mortality.

The social vulnerability literature to climate change has largely identified two conceptual frameworks of social vulnerability: outcome-oriented and context-oriented. The outcome-oriented framework reflects the IPCC definition of vulnerability. It has two aspects-such as starting point and ending point understandings (O' Brien et al. 2007). While the starting-point understanding largely attempts to analyse the potential initial impacts of climate change, the ending-point understanding deals with the residual impact in the sequence of causal interrelationships depending on changing climatic conditions, the sensitivity of the system and its ability to adapt it (Kelly and Adger 2000). But, the context-oriented framework presents a generalised picture of how socio-economic, political and institutional factors and extreme weather events interact with each other and shape the notion of social vulnerability (Murphy et al. 2015). It also discusses governance issues (Adger et al. 2009). Zarhan et al. (2008) and Murphy et al. (2015) outlined the manners in which governance determine the relevance, credibility, and legitimacy of different actions to local communities, as delineated in terms of criticality to formulating potential course(s) of action.

Several studies examined the causal factors of social vulnerability to climate change and variability in both Indian and other countries contexts. Adger (1999) attempted to understand the factors of social vulnerability to climate change from the political economy context in Xuan Thuy district of Coastal Vietnam. He found the link between inequality and social vulnerability in two ways: directly through increasing concentration of resources in fewer hands and thereby constraining coping ability through reduced resource entitlements; and indirectly through the enhancement of marginalisation and poverty.

Cutter et al. (2003) used normalised data and principal component analysis (PCA) and identified lack of access to resources including information, technology and knowledge; limited access to political decision-making power and social representation; social capital including social networks and connectedness; social beliefs and customs; health; density of infrastructure and networks as the indicators shaping the social vulnerability. Birkman (2006) mentioned that the notion of social vulnerability should not be limited to social fragilities, but should encompass the social inequalities about income, age or gender. Brouwer et al. (2007) concluded that households with lower income and less accessibility to natural assets are likely to face the greatest exposure to hazard risks in the context of Bangladesh. Hossain (2015) suggested the significant importance of physical and socioeconomic factors in determining human vulnerability at the household scale in the Bangladesh context. Chhotray and Few (2012) confirmed that recurrent hazards, poor adaptive capacity, and weak institutional support collectively contribute to ongoing social vulnerability in the context of Odisha. Bahinipati (2014) incorporated demography, agriculture and economic capacity as the main determinants of increasing socio-economic vulnerability in Odisha. Yadav and Barve (2017) concluded that population density, population growth rate, rural population, unemployment, capital loss due to cyclone and flood, households having no sanitary facilities, distance from cyclone shelter, and lack of logistic supports during cyclones are the significant indicators contributing to socioeconomic vulnerability in cyclone-affected communities in Odisha. Moreover, Dilshad et al. (2018) confirmed that the combination of structural inequities emanating from low landholding and the inability to shift their livelihood are the determining indicators of social vulnerability in the Hindu Kush Himalaya region. Senapati (2019) also pointed out covariate and idiosyncratic risks for assessing the vulnerability of agricultural households in Odisha. He highlighted the combination of non-dependence on farming, education level, size of land holdings, proximity to agricultural markets, farm experience by age, access to weather-related information and extension services and availability of greater credit amount to determine the vulnerability of agricultural households.

Anatomy of Social Vulnerability: A Causal Model

After conceptualising social vulnerability and reviewing its related literature, it is clear that the impact of climate change is inextricably associated with human conditions. These human conditions, which create resilience or vulnerability can be derived from the dynamic interaction of demographic, economic, institutional and social processes. The indicators under these four social vulnerability processes or factors and their functional relationship with climate change and variability have been comprehensively explained in Table 1.

Demographic factors: The demographic structure and composition of the households determine the resilience or vulnerability to climate change and variability. We have considered dependency ratio[1] and educational level. The household with a large dependency ratio tends to have economically and socially inactive members and make it more vulnerable to climate change. Logically, such households have to channel the resources in terms of finance and time towards the welfare of their inactive members (Nkondze et al. 2013, Wongbusarakum and Loper 2011) and consequently remained with the curtailed amount of resources for adding the capacity to cope with climate change impacts. Moreover, households with educated heads would have better access to climate change information and risk and skill attainment in climate-insensitive sectors (Eriksen et al. 2007, Leichenko and O' Brien, 2002). As a result, these factors enhance the capability to cope with climate change.

Economic factors: There is an agreement that a strong and robust economy can serve as an effective safety net against environmental stress and hazard exposure (Burton et al. 1993, Cannon 1994). Arguably, households with access to resources have better economic and social security, and consequently, granting them to withdraw other resources to stabilise their livelihood in case of impending climate change impacts. However, households with inadequate resource entitlements have to confront the problems of inability and dependence and consequently making them less resilient or more vulnerable to the shocks arising from climate change and variability. Under this, climate sensitivity occupation, access to formal credit, access to livestock and access to irrigation, average crop diversity, debt borrowed, changing paddy crop variety, changing crop planting dates, using early-maturing varieties of paddy, and migration are chosen as the indicators of social vulnerability.

Social factors: These relate to social engagement, social learning, beliefs, social networks and ethnicity of the households or communities that determine its resilience or vulnerability to climate change impacts. Social learning and beliefs are influenced by access to information and the type of information provided. Social networks serve as a mechanism of information delivery and a pathway for economic and social support (Dumenu and Obeng 2016). The point is that all these factors determine the level of awareness and knowledge about accessing resources and social engagement to cope and adapt to climate change events. Access to climate change information, engagement in community-level decision-making, farmers based organisation and political organisation are set for indicators of social vulnerability.

Materials and methods

Description of the study area

Ganjam district was selected out of 13 undivided districts in Odisha based on the highest rank of agricultural vulnerability index to climate change (Sahoo 2018). It is an agriculturally predominated district, characterised by the prevalence of two seasons: Kharif (June-September) and Rabi (October-January) seasons. It falls into the agro-ecological zone of East aSouth-Eastern Coastal Plain. Its climate is tropical characterised by high temperature and high humidity. Its soil is sandy loam, loam coastal alluvium and saline soil. Approximately 70% of the annual rainfall is received during the period from June to September. The annual normal rainfall for the period 1984-2016 is 1276mm.

Chhatrapur and Rangeilunda blocks were chosen for the study on the ground of the vulnerability to multiple hazards – such as flood, cyclone, and drought. These blocks were critically affected by flood following Super cyclone in 1999, super-cyclone Phailin in 2013 and cyclone Hudhud in 2014 (Yadav and Barve 2017). Eventually, Chamakhandi village of Chhatrapur block and Mandiapalli village of Rangeilunda block were selected as vulnerable zones for the study areas. Moreover, Chamakhandi village is better-off than Mandiapalli village in terms of agricultural development indicators – river irrigation, agricultural credit and marketing societies, and power supply for agricultural purpose.

Table 1 Social vulnerability factors, Indicators and indicator-vulnerability functional relationship

Vulnerability factors (Major components)	Indicators (sub-components)	Description of sub-components	Impact on vulnerability	Other studies using this indicator
Demographic factors	Household size	The average number of household members in each farm group	The larger the average size of the household, the greater likelihood of having economically inactive dependents and hence, contributing to vulnerability	Nkondze *et al.* (2013); Wongbusarakum and Loper (2011)
	Educational level	Percentage of households' heads having below primary education	Households having education below the primary level are more vulnerable to climate change than households with above primary education.	Wongbusarakum and Loper (2011)
Economic factors	Diversified sources of income	Percentage of households reporting at least one secondary source of income rather than farm income.	A diversified income basket serves as insurance against climatic shocks and reduces vulnerability.	Mustafa *et al.* (2011); Eriksen *et al.* (2007)
	Climate sensitive occupation	Percentage of households reporting agriculture as the only source of income	Households dependent on agriculture under changing climate are more likely to be vulnerable to the reduction of farm production and aftermath loss of employment.	Eriksen *et al.* (2007); Brooks *et al.* (2005); O'Brien *et al.* (2004)
	Access to formal credit	Percentage of households having access to formal credit	Households having more access to formal credit are less likely to be vulnerable to climate change.	Panda (2014)
	Access to livestock	Percentage of households having access to livestock	Households having income derived from the production of livestock are less likely to be vulnerable to climate change.	Panda (2014)
	Average Crop Diversity Index range (0-1)	The inverse of (number of crops grown by households +1). That is, if paddy and wheat are growing, the crop diversity index is 1/ 2+1 =0.33	Households having a greater number of crops are less vulnerable to climate change compared to households cultivating a single crop.	Panda (2014)
	Debt borrowed	Percentage of Households having borrowed during last 5 years	Households with debt outstanding are more vulnerable to climate change than non-borrowing households.	Panda(2014)
	Changing Paddy crop Variety	Percentage of Households who changed paddy crop variety	Farmers using different climate-resistant paddy crop varieties are less vulnerable to its counterpart.	Panda (2014)
	Changing crop planting dates	Percentage of households who changed crop planting dates.	Farmers who changed crop planting dates for the onset of rainfall are less vulnerable to climate change than other farmers.	Panda(2014)

Contd...

	Using early maturing varieties of Paddy	Percentage of households using early maturing varieties of paddy	Farmers using early maturing paddy varieties are less vulnerable to climate change and variability.	Panda(2014)
	Access to Irrigation	Percentage of Households having access to irrigation	Farm households with access to irrigation are less vulnerable to climate change and variability.	Panda(2014)
	Migration	Percentage of Households who have migrated members.	Households with at least one migrating member are less vulnerable to climate change than non-migrating households.	Panda(2014)
	Average Owned Land	Area of land in acres	Households with more average owned land are less vulnerable to climate change than their counterpart.	Panda(2014)
Social factors	Access to climate change information	Percentage of households having better access to climate change information	Households with better access to climate change information are less vulnerable to climate change.	Blaikie et al. (1994); Vincent(2004)
	Farm experiences	The average number of households	Farmers with more farm experiences are well known for the severity of climate change impacts and can better cope with it vis-a-vis the inexperienced farmers.	Panda (2014)
	Membership in community-level decision-making	Percentage of households having membership in community-level decision-making.	Farmers involved in community-level decision-making are probably less vulnerable to climate change due to the feeling of societal connectedness.	Adger *et al.* (2005)
	Membership in the farmer-based organisation	Percentage of households having membership in the farmer-based organisation.	Farmers membered in any farmer-based organisation are less vulnerable to climate change.	Adger *et al.* (2005)
	Membership in political organisation	Percentage of households having membership in political organisation.	Farmers having membership in any political organisation are less vulnerable to climate change.	Adger *et al.* (2005)

Data and sampling design

We used secondary and primary data. The secondary data on rainfall during the period 1901-2016 were collected from CMIE (Centre for Monitoring Indian Economy) Database. The data on maximum and minimum temperature during the period 1901-2002 were collected from India Water Portal.

The primary data have been collected during June-August 2018 through a structured household interview schedule. The simple random sampling technique has been used to collect primary data from 140 households from the developed village and 170 households from less developed villages. Table 3 presents the socio-economic characteristics of households in the study areas.

Methods

The index method has been used for the construction of the social vulnerability index as it can be fitted at any scale (household, district, national and global scale). Its construction is a sequential process - it involves different stages of selection and assessment of indicators. The validity of select indicators of social vulnerability has been checked with two arguments as to how replicable they are to yield consistent results and how far their underlying concepts are appropriate in that context (Fetami et al. 2017). There is also a

Table 2 Socio-economic characteristics of farm households

Characteristics	Chamakhandi village	Mandiapalli village	Overall
	Farmers' Groups		
Marginal	38(27.14)	59(34.71)	97(31.29)
Small	62(44.29)	44(25.88)	106(34.19)
Medium	14(10.00)	25(14.71)	39(12.58)
Large	26(18.57)	42(24.71)	68(21.94)
Overall	140(100.00)	170(100.00)	310(100.00)

Note The figures in parentheses are the percentage of total
Source Field survey

need for normalising the indicators as they are measured on different scales. We have applied a set of two methods of normalisation as in lyengar and Sudarshan (1982). If the "overall social vulnerability" increases with the increase in the value (s) of indicator(s), the normalisation equation (1) is used.

$$Index\, K_f = \frac{K_f - K_{min}}{K_{max} - K_{min}}$$

If the "overall social vulnerability" decreases with the increase in value(s) of indicator(s), the normalisation equation (2) is used.

$$Index\, K_f = \frac{K_{max} - K_f}{K_{max} - K_{min}}$$

Where K_f is the original value of sub-component for each farmers' and social group and K_{max} and K_{min} are the minimum and maximum values of each sub-component determined using data from all farm and caste groups of the village. For variables that show frequencies, for example, the percentage of farmers who have changed their crops, the minimum value was set at 0 and the maximum value at 100. After each indicator was normalized, the indicators are averaged to find out the value of each major component following equation (3).

$$K_h = \frac{\sum_{i=1}^{n} Index\, K_f^i}{n}$$

Where K_h is one of the four components of farmers that is, demographic, economic, and social components. *Index* K_f^i represents "the sub-components indexed by i, that make up for each major component, and n is the number of sub-components in each major component". Once the index values of demographic, economic and social factors are calculated, the social vulnerability (SV) of all farm groups and caste groups in their respective village will be found out as follows:

$$SV = f.\left[\frac{1}{n}\left(K_{DF} + K_{EF} + K_{IF} + K_{SF}\right)\right]$$

where, K_{DF}, K_{EF}, K_{IF} and K_{SF} are the index values of the demographic, economic, institutional and social factors, and n = the number of factors (major components) of social vulnerability.

Also, we have tested the Z test for the significance of the difference between two population proportions. The Z test under the null hypothesis is

$$Z = \frac{\left(\hat{p}_1 - \hat{p}_2\right) - 0}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \quad \text{under } H_0 : p_1 = p_2$$

Where $\hat{p} = \dfrac{y_1 + y_2}{n_1 + n_2}$. y_1 and y_2 are the number of adapting farmers in both groups: marginal and small; and medium and large farmers groups. n_1 and n_2 are the number of farmers (adapting and non-adapting) in both groups. p_1 and p_2 are the proportion of adapting farmers in total farmers in both groups.

If the calculated value of Z exceeds 1.96 or falls in the rejection region, we reject the null hypothesis and conclude that there is a significant difference between two population proportions.

Results and discussion

Perception on trend in climatic variables

Based on the recorded responses of the sampled household heads, changing rainfall pattern is cited as among the important manifestations of climate change and variability (about 96%). As far as the temperature pattern is concerned, about 97.14% and 95.29% of the household heads indicate an increase in inter-annual temperature. The above-noticed perceptions and views of farmers on climate change and variability are in line with the observed trends in meteorological variables. The analysis of meteorological variables exhibits an increasing trend in surface temperature and decreasing quantity of annual rainfall in the Ganjam district. Figure 2 depicts the anomalies of annual rainfall for the period 1901-2015. It shows that since 1901, the quantity of rainfall has, on average, been decreasing by about 0.08% every year. although rising trends are vividly observed in maximum and minimum temperatures (see Fig. 3). For the period 1901-2002, we have observed that maximum and minimum temperatures have, on average, increased by about 0.005^0C and 0.006^0C.

Social vulnerability of farmers' groups

The composite social vulnerability index among farm and caste groups is calculated as the unweighted average of vulnerabilities for demographic, economic and social factors. Figure 4 shows that the overall social vulnerability in the less developed village is more than

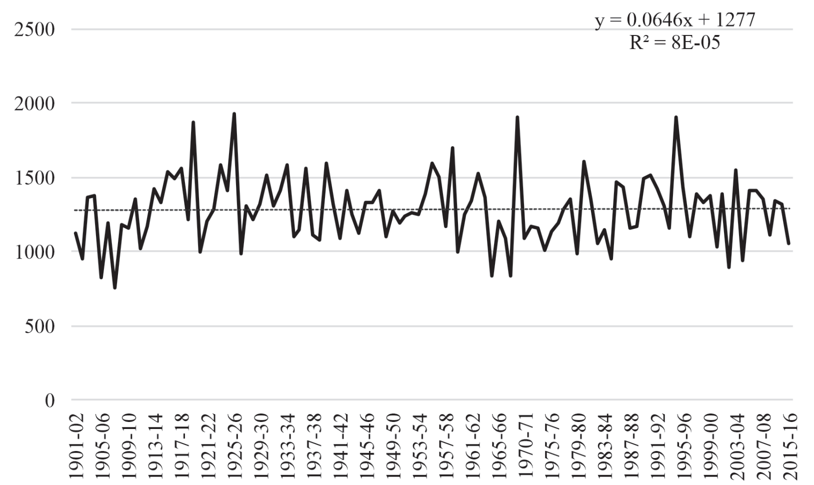

Figure 2 Trend of annual rainfall in Ganjam district, 1901-02 to 2015-16

Source Author's calculation from CMIE Database

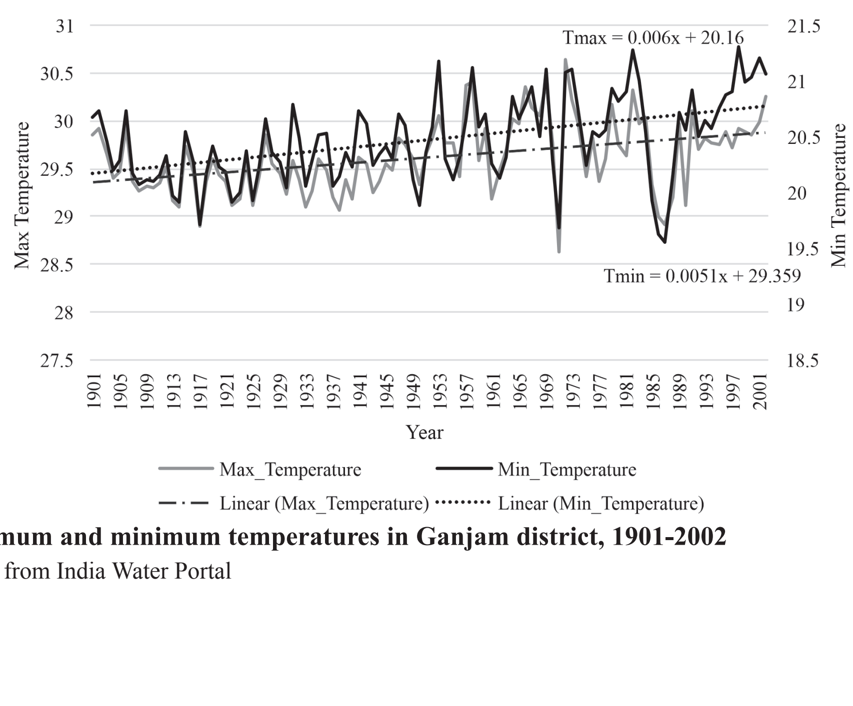

Figure 3 Trend of maximum and minimum temperatures in Ganjam district, 1901-2002

Source Author's calculation from India Water Portal

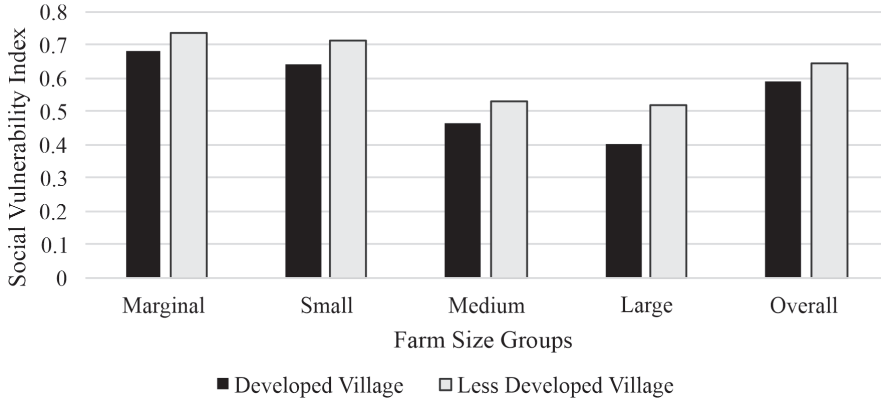

Figure 4 Social vulnerability among farm size groups in developed and less developed villages
Source Calculation from Household Survey 2017

in the developed village. In as much as the vulnerabilities for demographic, economic and social factors in the less developed village are relatively more than the developed village. Moreover, as far as the overall social vulnerability across farmers' groups is concerned, the marginal and small farmers groups are more vulnerable to the effects of climate change and variability than the medium and large farmers groups in both developed and less developed villages. The study reveals that the higher relative social vulnerability of marginal and small farm groups over other groups is attributed to the greater vulnerabilities of demographic, economic and social factors. If we look at a comparative picture of social vulnerability across farmers' groups in two sample villages, the marginal and small farmers' groups in the less developed village are more vulnerable to the effects of climate change and variability compared to the developed village.

Adaptation strategies

Table 3 and Table 4 show the list of adaptation strategies adopted by the sample farmers in both developed and less developed villages. The adaptation strategies adopted by the sample households are "using different varieties of seeds", "early maturing varieties of paddy", "changing planting dates of crops", "improved irrigation facilities", "crop diversification", "agroforestry", "livelihood diversification" and "migration". In our analysis, we further categorise these adaptation strategies into two different kinds. One kind of adaptation strategy aimed at enhancing the agricultural yield in the face of climate change and variability. Examples of this would include using different varieties of seeds, early maturing varieties of paddy, changing planting dates of crops, improved irrigation facilities, crop diversification and agroforestry. The second kind of adaptation strategies such as livelihood diversification and migration, aimed at improving farmers' welfare in ways that reduce the agricultural yield. These measures generally have to do with diversifying farmer income so that the vulnerability to climatic shocks can be reduced. While it is clear that both kinds of adaptation strategies are equally important and can benefit the farmers.

Tables 3 and 4 show the adaptation strategies adopted by two broad different categories of farmers in

Table 2 Farm size-wise components of social vulnerability in developed and less developed villages

Component	Developed					Less developed				
	Marginal	Small	Medium	Large	Overall	Marginal	Small	Medium	Large	Overall
Demographic	0.558	0.527	0.434	0.345	0.492	0.617	0.670	0.433	0.399	0.550
Economic	0.784	0.687	0.389	0.333	0.621	0.787	0.732	0.483	0.473	0.651
Social	0.707	0.702	0.564	0.522	0.656	0.798	0.741	0.673	0.687	0.737

Source Field survey

developed and less developed villages. We will explain each adaptation strategy separately.

Using different varieties of seeds: The sample farmers use mixed varieties of seeds while cultivating paddy in their respective land. As it was clear that the traditional varieties are more prone to the incidence of weeds and pests due to the occurrence of climate change and variability. Instead of sowing these traditional varieties, some of the farmers are using the modern high-yielding resistant varieties which are least affected by climate change and variability. Most importantly, the use of mixed varieties of seeds for paddy may enable the farmers to maintain a certain level of productivity and farm income. Tables 3 and 4 show that the farmers adopting this strategy under the medium and large group is significantly different from those under the marginal and small group.

Early maturing varieties of paddy: Generally, the traditional varieties of paddy seeds are late maturing. For example, Sarad, Laxmi 18, and LSP 21 are notable examples of traditional varieties of paddy seeds grown in the study areas. Hence, it is most affected by the impacts of extreme climatic events such as floods and drought. As the farmers suggested that early maturing varieties of paddy were sown and harvested before the happening of flood and drought in September and October every year. What they mentioned was that early harvested production of paddy fetched attractive prices and enabled them to maintain relatively high farm income only due to the short duration varieties of paddy. It is clear from Tables 3 and 4 that about 36% of farmers in the developed village adopted early maturing varieties of paddy as compared to the less developed village (about 30%). If we analyse the group-wise break-up in both the study areas, we found that the medium and large group is more adaptive to using early maturing varieties of paddy than the marginal and small group.

Changing planting dates of crops: Changing the planting dates of crops was reported as the most widely used adaptation strategy in the face of climate change and variability in the study areas. Farmers shift the planting dates from year to year, particularly in the rain-fed environment in which they have to wait for the onset of the rainy season to start planting. The purpose of changing the planting dates is to increase the crop yields under the changed climatic condition. In our study areas, farmers learnt the experience from the changing rainfall patterns and applied the same on the decision to change the planting dates of crops which most often help maintain the agricultural yield. It is revealed from tables 3 and 4 that about 59% of sample farmers in the developed village use this strategy to adapt to the negative impacts of climate change and variability on crop yield as compared to the less developed village (43%). And also, the medium and large farmers are the most adopter of this adaptation strategy as compared to the marginal and small farmers.

Table 3 Adaptation strategies adopted by different vulnerable groups in developed village

Adaptation strategies	Marginal and Small Group (n_1=100)	Medium and Large Group (n_2=40)	DIFF[b]	Z	Whole Sample (n=140)
		Agricultural adjustment			
Using different varieties of seeds	48	75	27[b]	-2.91	56
Early maturing varieties of paddy	32	48	16[ns]	-1.72	36
Changing planting dates of crops	49	83	34[b]	-3.64	59
Improved Irrigation facilities	22	78	56[b]	-6.12	38
Crop Diversification	15	63	48[b]	-5.62	29
Agroforestry	25	48	23[b]	-2.59	31
		Non-agricultural adjustment			
Livelihood diversification	32	17.5	14.5[ns]	1.73	28
Migration	14	15	1[ns]	-0.15	14

[a]DIFF is a difference value between two samples

[b]is significant at 5 % and [ns] is non-significant based on Z-test for the difference between two sample proportions.

Table 4 Adaptation strategies adopted by different vulnerable groups in less Developed village

Adaptation strategies	Marginal and Small Group (n_1=103)	Medium and Large Group (n_2=67)	DIFF[b]	Z	Whole Sample (n=140)
		Agricultural adjustment			
Using different varieties of seeds	21	46	25[b]	-3.43	31
Early maturing varieties of paddy	16	52	37[b]	-5.10	30
Changing planting dates of crops	35	55	20[b]	-2.61	43
Improved Irrigation facilities	19	79	60[b]	-7.68	43
Crop Diversification	11	45	34[b]	-5.08	24
Agroforestry	15	9	6[ns]	1.09	12
		Non-agricultural adjustment			
Livelihood diversification	32	31	1[ns]	0.10	32
Migration	25	16	9[ns]	1.36	22

[a]DIFF is a difference value between two samples
[b]is significant at 5 % and [ns] is non-significant based on Z-test for the difference between two sample proportions.

It is evident from the tables that the difference between these two groups is significant at a 5% level in both developed and less developed villages.

Improved irrigation facilities: Among all adaptation strategies, improved Irrigation facilities are the important adaptation strategy to alleviate the negative impacts of climate change in the face of erratic and untimely rainfall in our study areas. This strategy helps in increasing the agricultural yield because they have access to water even in the eventuality of water shortage and less rainfall. What the adapting farmers reported is that the irrigation facilities can be improved through ponds, wells and borewells. Introducing irrigation structure into the currently rain-fed system was cited by many farmers as the autonomous adaptation action. As responded by the adapting farmers, this not only solves the problem of water stress but also expand the opportunities for switching planting dates of crops as well as increase the returns on investment in chemical fertilisers, pesticides and other agricultural inputs. Tables 3 and 4 indicate that about 43% of sample farmers in the less developed village (rain-fed village) used improved irrigation facilities as compared to the developed village. Also, an interesting finding was revealed that the medium and large farmers' group is capable of incurring a high cost of irrigation as compared to the marginal and small farmers' group.

Crop diversification: Diversification to oilseeds from paddy and wheat is the well-acknowledged adaptation strategy to deal with the adverse consequences of climate change and variability in the study areas. It was clear from the study that the area under the cultivation of oilseeds is increasing from 2013-14 to 2016-17, while the areas under the cultivation of different varieties of paddy such as Kulia, Pradhan, Saria, Kusma and Karni are decreasing over the same period. The reasons for these trends are the relatively high profitability of oilseeds and changing rainfall patterns due to the occurrence of climate change and variability. This strategy is not so popular as compared to other adaptation strategies. It is clear from tables 3 and 4 that about 29 and 24% of farmers are adopting this strategy to adapt to the impacts of climate change in both the study areas. Also, if we analyse the adoption of this adaptation strategy within each study area, it was found that the medium and large farmers are the most adaptive to this strategy

Agroforestry: Keeping in mind that farm practices and land management are keys to sustainable agriculture, sample farmers use agroforestry to reap the double dividends of adaptation to and mitigation of adverse impacts of climate change and variability. Agroforestry in the developed village is relatively more popular than the less developed village. This is clear from tables 3 and 4. Mostly, the medium and large farmers use it as an adaptation strategy to mitigate the negative consequences of climate change and variability.

Livelihood diversification: Based on the fact that the non-agricultural income sources are relatively less climate-sensitive than the farm income, livelihood diversification out of agriculture is the most promising adaptation strategy to redress the adverse impacts of climate change (Paltasingh and Goyari 2015). Farmers in both the study areas reported that engaging themselves in non-farm activities play a compensatory role in the risky agricultural production due to the rainfall fluctuations. The field survey revealed that farmers in times of the decline in agricultural productivity generally diversify to non-farm businesses such as shopkeeping, rickshaw pulling, and woodworker. Tables 3 and 4 reveal that about 28% and 32% of farmers in the developed and less developed villages adopted livelihood diversification to adapt to the declining productivity in agriculture due to climate change and variability. And also, the difference in percentages of farmers between the two groups is not significant. However, when all experience a yield (and thus income) decline simultaneously, the demand for agricultural wage labour and off-farm goods and services will also likely decline (Jayachandran 2006).

Migration: In our study areas, migration is mainly caused by two factors such as the existence of climate-sensitive farm-based jobs and the non-availability of climate-insensitive non-farm based jobs. The remittances of migration to semi-urban and urban areas are the effective means of adapting to the negative effects of climate change on agriculture. In our study areas, very few farmers migrated to cities in search of a job. It is clear from Tables 3 and 4 that about 22% and 14% of farmers in less developed and developed villages respectively migrated.

Conclusion

Climate change is an irreversible change in the climatic conditions which puts the agricultural food production system and food security at risk. As far as the different categories of farmers are concerned, the small and marginal farmers are socially more vulnerable to climatic risks than the medium and large farmers because of their weak economic and social conditions irrespective of the development levels of selected villages. In this context, adaptation is the key to reducing the severe climatic impacts and building the resilience of the agricultural system. This will help the policymakers to achieve the goal of sustainable development in agriculture and reduce the poverty and hunger in the masses.

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The impact of public expenditure on agricultural growth: empirical evidence from Punjab, India

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Abstract This paper has assessed the impact of public expenditure on the agricultural growth in Punjab during 1990-91 to 2019-20. The expenditure on crop husbandry, dairy development, and agricultural research & education had a positive and significant impact on the state's agricultural growth, but the expenditure on soil & water conservation and forestry & wildlife did not impact it. The study confirms that the growth in the agricultural gross domestic product has led to the growth in public expenditure in agriculture. However, the lack of reverse causal flow from the total public expenditure to agricultural growth discloses that public sector expenditure in agriculture is not optimally allocated and needs reprioritization.

Keywords Public expenditure, Agricultural growth, Punjab agriculture, Wagner's law

JEL Codes H72, O49, O13

Several studies have examined the effects of public expenditure on economic growth and have yielded mixed results. While some have established a positive impact (Ram 1986, Shuaib et al. 2015, Chandio et al. 2016, Guandong and Muturi 2016, Akarue and Eyovwunu 2017), others find it negative (Kormendi and Meguire 1985, Diamond 1989). On the other hand, Landau (1986) and Scully (1989) do not find any relationship between public expenditure and economic growth. Satter (1993) observed that public spending has no impact on the economic growth of the developed countries but a positive impact in the developing countries. Such studies aim to determine the applicability of Wagner's or Keynesian hypothesis. Wagner's law emphasizes economic growth as the fundamental determinant of public expenditure (Wagner 1883), while the Keynesian approach treats public spending as a fundamental determinant of economic growth (Keynes 1936). Studies by Salih (2012) for Sudan, Srinivasan (2013) for India and Wang et al. (2016) for Romania support Wagner's law, whereas the studies by Okezie et al. (2013) and Guandong and Muturi (2016) for South Sudan support the Keynesian hypothesis.

Awokuse (2009) argues that agriculture's potential contribution to the economic growth of developing countries is a matter of debate. Such arguments have coincided with the early works (Lewis 1954, Fei and Ranis 1961, Jorgenson 1961, Johnston and Mellor 1961, Schultz 1964). The studies by Schultz (1964) and Timmer (1995) support that investment in agriculture and the development of infrastructure and institutions are prerequisites for economic growth. These studies highlight that agricultural growth acts as a catalyst for overall economic growth, as it affects rural incomes and provides resources for structural transformation (Dowrick and Gemmell 1991, Datt and Ravallion 1998, Thirtle et al. 2003). Therefore, public expenditure is of vital importance to agricultural growth, and any reduction in it may adversely affect the performance of agriculture. Instability in public expenditure in agriculture is also inversely related to growth (Selvaraj 1993).

The Punjab economy is mainly dominated by agricultural production and small and medium-sized enterprises. During the mid-1960s, the success of the Green Revolution sparked agricultural growth and a faster increase in the gross domestic product (GDP) from agriculture. However, in the last two decades, agricultural growth has started showing stagnation. According to a study by the Indian Council for Research on International Economic Relations (ICRIER), the growth rate dropped to 3% during 1986-87 to 2004-05 and further to 1.61% during 2005-06 to 2014-15, which is almost half the all-India average of 3.5%. Apart from stagnating productivity, shrinking landholdings, declining profitability, and climate change, the crisis in the agriculture sector of Punjab is also attributed to populist policies such as free electricity for irrigation and a corresponding decline in the public expenditure in agriculture. This study attempts to examine the impact of public spending on the growth of the agricultural sector of Punjab and draw lessons for higher agricultural growth in future.

Data

The study uses time-series data on public expenditure on agriculture and gross state domestic product from agriculture (GSDP) for 1990-91 to 2019-20 from the Reserve Bank of India Publications - State Finances: A Study of Budgets, and the Directorate of Economics and Statistics, Government of Punjab. The annual agricultural GSDP time series data are a proxy for growth in agriculture. The study considers spending on crop husbandry, soil & water conservation, animal husbandry, dairy development, fisheries, forestry & wildlife, and agricultural research & education. The time-series data of all the variables were deflated at 2011-12 constant prices using GDP deflator and are expressed in Rupees Crores. To avoid double-counting, the loans, advances, and central government expenditure were not considered.

Methodology

Stationarity tests

To check the stationarity of the variables, the Augmented Dickey-Fuller (ADF) test was employed.

$$\Delta Y_t = \beta_1 + \beta_{2t} + \delta Y_{t-1} + \Sigma_{i\text{-}1}^{m} a_i \Delta Y_{t-1} + u \qquad \dots (1)$$

Where Y_t is the expenditure or agricultural GSDP in year 't', ΔY_t is the difference of the series Y and u is the pure white noise error term. β_1 is the constant, and β_2 and δ are the parameters to be estimated. Further, m is the optimal lag value selected based on the Akaike information criterion (AIC). The test has the null hypothesis that the variable has a unit root, indicating that the series is non-stationary.

Model specification

The econometric model was chosen after examining the correlation between explanatory variables to avoid multicollinearity. Therefore, the variables fisheries and animal husbandry, which are highly correlated with other explanatory variables, are excluded.

Thus, the model is specified as:

$$\ln AgGSDP = C + \beta_1 \ln Crop + \beta_2 \ln Soil + \beta_3 \ln Dairy + \beta_4 \ln Forest + \beta_5 \ln AgRes + u \qquad \dots(2)$$

Where,

AgGSDP = Agricultural gross state domestic product

Crop = Expenditure on crop husbandry

Soil = Expenditure on soil & water conservation

Dairy = Expenditure on dairy development

Forest = Expenditure on forestry & wildlife

AgRes = Expenditure on agricultural research & education

C = constant term

u = error term

β_n = coefficients of the respective variables

Causality tests

The Granger causality test provides the causal relationship between agricultural GSDP and public expenditure. It tests the hypothesis of predicting a particular variable's future values while incorporating the past lags of other variables in the model. If the coefficients of the lagged variables in the equation turned out to be statistically significant, then the explanatory variable does not granger cause the dependent variable. An autoregressive distributed lag (ADL) model for the Granger-causality test is given below:

Table 1 Descriptive statistics

Item of expenditure	Amount (in Rupees Crores at 2011-12 prices)			Standard deviation
	Min.	Max.	Mean	
Crop husbandry	118.22	8223.48	1188.24	2206.22
Soil & water conservation	40.77	106.11	64.25	16.96
Animal husbandry	113.00	350.40	212.95	75.52
Dairy development	4.72	43.26	12.19	9.18
Fisheries	6.63	21.43	11.30	3.28
Forestry and wildlife	36.26	286.20	108.89	59.40
Agricultural research & education	115.97	332.16	189.04	68.39
Agricultural GSDP	35928.11	101048.59	62469.78	18898.67

Source Authors' compilation from RBI publications and Economic and Statistical Office, Govt. of Punjab.

$$\Delta X_t = \Sigma_{i=1}^{m} \alpha_i \Delta Y_{t-1} + \Sigma_{j=1}^{m} \beta_j \Delta X_{t-1} + u_{1t} \qquad \ldots(3)$$

$$\Delta Y_t = \Sigma_{i=1}^{m} \sigma_i \Delta Y_{t-1} - \Sigma_{j=1}^{m} \delta_j \Delta X_{t-1} + u_{2t} \qquad \ldots(4)$$

Where α, β, σ, and δ are the coefficients of the respective variables, t represents time while i and j are their lags, U_{1t}, and U_{2t} are the error terms. Y and X are the agricultural GSDP and public expenditure, respectively.

Results and discussion

The descriptive statistics of agricultural GSDP and public expenditure on agricultural and allied sectors are given in Table 1. The average agricultural GSDP of Punjab has been estimated at Rupees 62469.78 crores. The average expenditure is the highest on crop husbandry and the lowest on fisheries.

Trend and composition of expenditure

Figure 1 shows the trend (three-year moving average) of Punjab state's public expenditure on agriculture and allied sectors at 2011-12 prices. The revenue expenditure (RE) is much higher than the capital expenditure (CE). The capital expenditure declined from 2000-02 to 2002-04, and after that, it increased continuously. On the other hand, the revenue expenditure increased during 2000-02 to 2001-03, then declined immediately, and remained almost constant during 2002-04 to 2011-13. The revenue expenditure increased sharply since 2011-13 and thus, resulted in a sharp increase in the total expenditure (TE).

Figure 2 depicts the share of agriculture and the allied sector in the GSDP and the amount of public expenditure as % of total developmental expenditure,

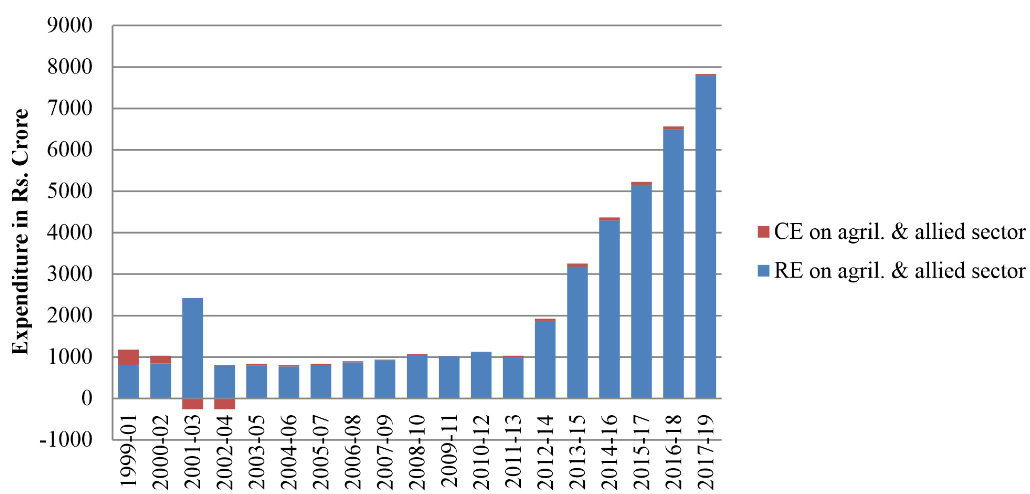

Figure 1 Trends in public expenditure on agriculture & allied activities
Source Authors' compilation

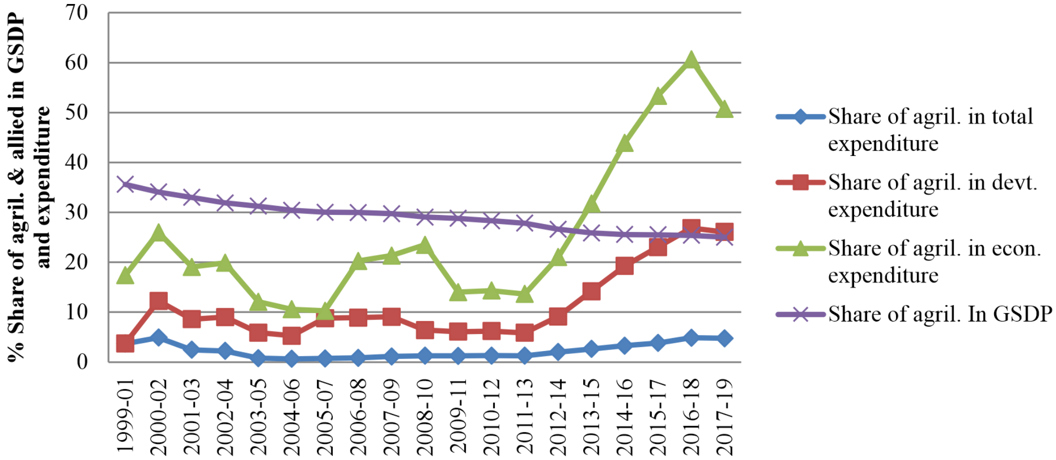

Figure 2 The share of agriculture & allied activities in GSDP and expenditure
Source Authors' compilation

total economic expenditure, and total expenditure at 2011-12 prices. The share of agriculture and the allied sector in GSDP has declined slowly. The share of public expenditure on agriculture and the allied sector as % of the total economic expenditure and total developmental expenditure has shown ups and downs but increased significantly in 2011-13, declining again after 2016-18. The share in the total spending has also established a declining trend till 2004-06, remaining constant from 2004-06 to 2011-13 and showing an increase, later. As a result, the average share of agriculture and the allied sector in the GSDP was 29.15%, and the average share of public expenditure on agriculture and the allied sector in the total expenditure, total developmental expenditure, and total economic expenditure were 2.30, 11.29, and 25.45 %, respectively.

The composition and annual growth rate of the public expenditure on agriculture and allied sectors and agricultural GSDP are shown in Table 2. The agricultural GSDP showed an increasing trend with an annual growth of almost 3.3% during 1990-2009 to 4.08% annually during 2010-2019. The expenditure on crop husbandry showed negative annual growth of -3.07% during 1990-99 but increased at 8.18% annually during 2000-09 and much faster 51.50% per annum during 2010-2019. The growth rate of soil & water conservation, animal husbandry, fisheries and agricultural research & education sectors was also positive but relatively slow. In the dairy development

Table 2 Composition and compound annual growth rate of AgGSDP and public expenditure on agriculture & allied sector (at 2011-12 prices)

Year/sector	Crop husbandry	Soil & water conservation	Animal husbandry	Dairy	Fisheries	Forestry & wildlife	Agril. research & education	AgGSDP
				Public expenditure and GSDP (in Rs. Crores)				
1990-99	170.34	54.04	137.46	7.13	8.17	663.09	125.50	44648.50
2000-09	172.51	58.50	194.48	15.45	10.77	146.49	177.89	57313.53
2010-19	3221.87	80.23	306.92	14.00	14.96	117.11	263.75	854473.13
				CAGR (%)				
1990-99	-3.07	2.76	3.63	-2.73	2.67	7.55	1.96	3.29
2000-09	8.18	1.34	1.71	22.08	2.02	-10.75	0.15	3.30
2010-19	51.43	2.25	3.33	-8.50	1.63	10.32	6.41	4.08

Source Authors' compilation from RBI publications and Economic and Statistical Office, Govt. of Punjab.

sector, the growth rate was negative during 1990-99 and 2010-19. There was a negative growth rate of -10.75% per annum in the forestry & wildlife sector during 2000-09, but it became positive at 7.55% per annum during1990-99 and 10.32% per annum during 2010-19, respectively.

Augmented Dickey-Fuller (ADF) test

To check the stationarity of the variables, the Augmented Dickey-Fuller (ADF) test has been conducted and the results are shown in Table 3. The time series of all the variables are non-stationary at the level. However, at the first difference, all the variables' absolute t-statistic value is found greater than their critical values, with the p-values being significant. This indicates that the series is free from the unit root and is integrated at order one.

Effects on growth

The regression results are presented in Table 4. To avoid multicollinearity, the variables were selected based on the correlation matrix. As animal husbandry and fisheries variables were highly correlated with other variables, these were omitted from the analysis. The regression coefficient of crop husbandry indicates that each percentage increase in expenditure on crop husbandry increases the real agricultural GSDP by 0.09%. These findings are supported by Ighodaro (2006), Faleyimu (2013), and Oyetade and Dewi (2014). Dairy development is also found to have a significant and positive impact; with a 1% increase in public expenditure on dairy development, the real agricultural GSDP of Punjab increased by 0.10%. These findings are consistent with this Revoredo-Giha (2015) and Chandio et al. (2017). Likewise, the public expenditure on agricultural research and education has a significant and positive impact on Punjab's agricultural economy; a 1% increase in public spending increases the real agricultural GSDP by 0.35%. These results are in line with Alston et al. (2000) and Mogues et al. (2012). On the other hand, the variables soil & water conservation and forestry & wildlife are found to have no significant impact on the agricultural GSDP.

The results of the Granger causality tests are shown in Table 5. The VAR Lag Order Selection Criteria was followed to select the appropriate number of lags. Accordingly, a lag of one was selected and used to check the causal relationship between various categories of public expenditures in agriculture and agricultural GSDP. The results reveal that the variables

Table 3 Results of unit root test of the variables

Expenditure	At level & 1st difference	t-statistic value	Critical value	p-value	Remarks
Crop husbandy	Level	-0.06	-3.67	0.95	Non-stationary
	First difference	-5.65	-3.68	0.00*	Stationary
Soil & water conservation	Level	-2.86	-3.67	0.06	Non-stationary
	First difference	-7.07	-3.69	0.00*	Stationary
Animal husbandry	Level	-0.04	-3.67	0.95	Non-stationary
	First difference	-6.37	-3.68	0.00*	Stationary
Dairy development	Level	-2.56	-3.67	0.11	Non-stationary
	First difference	-7.95	-3.68	0.00*	Stationary
Fisheries	Level	-0.69	-3.68	0.83	Non-stationary
	First difference	-9.88	-3.69	0.00*	Stationary
Forestry & wildlife	Level	-1.13	-3.67	0.68	Non-stationary
	First difference	-3.90	-3.68	0.00*	Stationary
Agricultural research & education	Level	-0.95	-3.68	0.75	Non-stationary
	First difference	-7.36	-3.68	0.00*	Stationary
Agricultural GSDP	Level	- 0.30	-3.67	0.91	Non-stationary
	First difference	-5.60	-3.68	0.00*	Stationary

Source Authors' calculations
Note *indicates significance at 1 % level.

Table 4 Regression results of determinants of agricultural growth in Punjab

Explanatory variable	Coefficient	Standard error	t-statistic	p-value
ln Crop	0.09	0.29	3.17	0.00*
ln Soil	0.02	0.13	0.21	0.83
ln Dairy	0.10	0.04	2.41	0.02**
ln Forestry	0.03	0.06	0.63	0.53
ln AgRes	0.35	0.15	2.32	0.02**
Constant	9.84	1.06	9.23	0.00*
R-squared	0.85			
Adj R-squared	0.82			
F-statistic	28.59			

Source Authors' calculations
Note * and ** indicate significance at 1% and 5% levels, respectively.

Table 5 Results of pairwise Granger causality test

Null hypothesis	F-statistics	p-value	Granger	Remarks
Expenditure on crop husbandry does not Granger cause AgGSDP	0.40	0.52	No	Unidirectional
AgGSDP does not Granger cause expenditure on crop husbandry	5.72	0.02**	Yes	
Expenditure on soil & water conservation does not Granger cause AgGSDP	1.18	0.28	No	Unidirectional
AgGSDP does not Granger cause expenditure on soil & water conservation	6.75	0.01**	Yes	
Expenditure on animal husbandry does not Granger cause AgGSDP	2.95	0.09***	Yes	Bidirectional
AgGSDP does not Granger cause expenditure on animal husbandry	16.22	0.00*	Yes	
Expenditure on dairy development does not Granger cause AgGSDP	0.07	0.79	No	None
AgGSDP does not Granger cause expenditure on dairy development	0.85	0.36	No	
Expenditure on fisheries does not Granger cause AgGSDP	3.87	0.05**	Yes	Bidirectional
AgGSDP does not Granger cause expenditure on fisheries	14.75	0.00*	Yes	
Expenditure on forestry & wildlife does not Granger cause AgGSDP	3.28	0.08***	Yes	Bidirectional
AgGSDP does not Granger cause expenditure on forestry & wildlife	3.74	0.06***	Yes	
Expenditure on agril. research & education does not Granger cause AgGSDP	0.55	0.46	No	Unidirectional
AgGSDP does not Granger cause expenditure on agril. research & education	8.05	0.00*	Yes	
Total expenditure on agriculture does not Granger cause AgGSDP	0.40	0.53	No	Unidirectional
AgGSDP does not Granger cause total expenditure on agriculture	5.78	0.02**	Yes	

Source Authors' estimation
Note *, **and *** indicate significance at 1% , 5% and 10% levels, respectively.

of crop husbandry, soil & water conservation, agricultural research and education were Granger caused by agricultural GSDP in a unidirectional way; however, the animal husbandry, fisheries and forestry & wildlife have a bidirectional causal relationship with agricultural GSDP. Again, the pairwise causality test result between the total public expenditure and agricultural GSDP has shown that agricultural GSDP Granger causes total public expenditure in agriculture. These findings support Wagner's law, i.e., economic growth is a determinant of the public sector expenditure (Salih 2012, Srinivasan 2013, Wang et al. 2016, De

2018). Moreover, the lack of reverse causal flow from the total public expenditure in agriculture to agricultural GSDP discloses that agricultural and allied activities in the state have been neglected and are poorly managed. Therefore, the performance and share of agricultural and allied sectors in economic development have been declining in Punjab.

Conclusion and policy implications

This paper studied the impact of public expenditure in agriculture on agricultural growth in Punjab. We found that the GSDP from agriculture granger causes expenditures on crop husbandry, soil & water conservation and agricultural research & education unidirectionally; however, animal husbandry, fisheries and forestry have a bidirectional causal relationship with agricultural GSDP. Again, the pairwise causality test results between the total public expenditure on agriculture and agricultural GSDP have shown the causality of agricultural GSDP to the total public expenditure agriculture sector. This finding supports Wagner's law, i.e., economic growth is a determinant of public sector expenditure. The prevalence of Wagner's law points to the fact that public expenditure is not optimally allocated across various sectors. It calls for a reprioritization of public spending in agriculture to boost future agricultural growth in Punjab. While the public expenditure needs to be curbed across unproductive sectors, it needs to be expanded to the more productive sub-sectors of agriculture such as crop husbandry, dairy development and agricultural research & education.

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A critical analysis of India's Contract Farming Act 2020

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Abstract This paper critically analyses the recently passed "Farmers (Empowerment and Protection) Agreement on Price Assurance and Farm Services Act, 2020". Based on a systematic review of the literature using keyword search strategy from Scopus, Economic and Political Weekly, Google Scholar, and other government-published documents, this paper contends farmers are likely to have less onus of power in contract farming than corporate agencies. A thorough analysis of selected studies and comparison with the new Act reveals that farmers may benefit from legal assistance, farm service, market and price assurance, and insurance coverage once it goes into effect. The Act is not without flaws, and small farmers' participation remains a source of concern. This paper identifies the Act's flaws in light of reviewed studies and advocates that the government shall consider incorporating FAO's concept of "Responsible Contract Farming" to strengthen farmers' hands and make the Act a more transparent practice.

Keywords Contract farming, Contract farming act, Responsible contract farming, Contract farming in India

JEL Codes Q13, Q18

The Government of India (GOI) has passed two other farm bills[1] in addition to the "Farmers (Empowerment and Protection) Agreement on Price Assurance and Farm Services Act, 2020" (Government of India, 2020a), commonly known as 'Contract Farming Act 2020'(CFA 2020). After both houses of the Parliament passed the three bills, the President of India gave his assent to become Acts of the Parliament. Soon after, amid the Covid-19 pandemic, the country witnessed farmers' protests opposing the farm Acts, and later, the Supreme Court (SC) of India ordered the Acts to be put on hold and appointed a panel to submit a report on the contentious Acts.

The GOI anticipated that this CFA 2020 (this paper only focuses on the CFA, 2020) would result in a standardized national framework for farming agreements that would protect and empower farmers when negotiating with agri-business firms, processors, wholesalers, exporters, or large retailers. This Act will facilitate access to farm services and the sale of future agricultural products in a transparent manner through mutually agreed-upon remuneration and a fair price structure. In contrast, others express concern about corporate manipulation, land grabbing, and other forms of exploitation. In this quandary, understanding the potential benefits and drawbacks of the new Act requires looking beyond the expectation that designed by the government and critics elevated in opposing the Act by agitated farmers and others. Based on the critically systematic review, this paper demonstrates the CFA 2020 and elaborates on potential benefits and loopholes that may emerge once this Act takes effect.

The Challenge of *'Front-end'* and *'Back-end'* Activities

Before delving into the potential benefits and

[1]Farmers' Produce Trade and Commerce (Promotion and Facilitation) Act, 2020, and Essential Commodities (Amendment) Act, 2020.

drawbacks of the CFA 2020, it is indispensable to understand the current agricultural landscape and challenges, particularly for small farmers in India. The priority should be given to small and marginal farmers (0.00-2.00 ha) when developing policies, as they constituted 86.08% holdings in 2015-16 (Government of India 2020b). Further, the agricultural sector is currently confronted by several challenges: a declining trend in the share of the *agriculture workforce*, *Gross Value Added (GVA)*, and *Gross Cropped Area (GCA) under food crops*. The share of the workforce engaged in agriculture has declined over the last decade from 52.50% in 2009 to 42.60% in 2019 (Statista 2021). Agriculture' share of GVA fell by about 2.3% between 2011-12 and 2014-15, from 18.4% to 16.1%, owing to an increase in the service sector (Government of India 2016). The GCA for food crops has decreased from 81.2% in 1950-51 to 71.6% in 2012-13 (Government of India 2017), which may lead to food scarcity in future as demand proliferates. Despite the decline in food crops, the area under other food grains, particularly high-value crops with a greater emphasis on fruits and vegetables, has grown significantly. During 2005-06 to 2015-16, horticulture production has increased from 182.81 million tonnes to 286.19 million tonnes (Government of India 2017), which are predominantly cash-intensive and perishable, that necessitate advanced management, immediate transportation, good market connectivity, cold storage, etc.

Also, the *'back end'* activity trends, such as cultivation shifting towards fragmentation rather than consolidation. The Agriculture Census Report (2015-16) demonstrates that the number of operational holdings in India increased from 71 million to 146.50 million between 1970-71 and 2015-16. This increasing number of operational holdings has resulted in a decline in India's average operational landholdings. The average size of operational holding has declined to 1.08 ha. in 2015-16 (Government of India, 2020b). In development economics, there is a stylized fact that a strong inverse relationship exists between land size and productivity (Fan and Chan 2005). Besides, it has been argued that small farmers are more likely than large farmers to be efficient in terms of land productivity because the share of family labour on small farms is much higher (Gulati et al. 2008). Small farmers can cultivate intensively with family labour, which can be more productive, whereas large farmers are more efficient in technical and allocative efficiency (Jha et al. 2000).

Further, small farmers often produce a small surplus, for which they often face high transition coast to sell produces. Besides that, due to landholding fragmentation and shifting food demand, small farmers face challenges in organizing *'back end'* activity. The increasing demand for high-value crops and the issues mentioned above raise the question: *how small farmers can survive in the face of globalization?*

Although the *'front-end'* activities become more challenging for small and marginal farmers. Globalization has consolidated the *'front-end'* activity, for example, the post-harvest activities, i.e., allowing direct procurement through the private sector, agro-processors, processing industries, retail businesses, and advanced supply chains. While the 'back-end' activities are still fragmented and will continue to be fragmented. The challenge is to establish a link between the two end activities regarding access to farm services, a secure market, a remunerative market price, quality inputs, extension services, and so on. So it is not unfair to say that the future of Indian agriculture development, particularly the efficiency of small and marginal farmers, will be dependent on the successful integration of these two end-activities. In many developing countries, contract farming has been promoted to integrate the two end-activities and provide farm services to small and marginal farmers from agro-processors, traders, and sponsors.

The Political Economy of Contract Farming

"Contract farming refers to a system for the production and supply of agricultural produce under forwarding contracts, the essence of such contracts being a commitment to provide an agricultural commodity of a type, at a time and a price, and in quantity required by a known buyer" (Singh 2002a). It considers as a form of vertical coordination in which firms/sponsors assist farmers throughout the harvest or marketing process by providing inputs, extension services, and secured output markets (Singh 2005; Ba et al. 2019). This farming practice also establishes the links between farm and firm partnerships in access to credit, modern technology, reducing market risks, securing market price, and insurance coverage (Little and Watts 1994; Hudson 2000; Singh 2005).

However, according to scholars who hold a political-economic outlook have divulged opinions that contract farming is essentially a method by which agribusiness companies shift production risks to small farmers while gaining control over farmers' labour and land (Wilson 1986, Watts 1992, Little and Watts 1994, Raynolds 2000, Singh 2002a). In addition, farmers may lose their universal autonomy (Schrader 1986), which increases production risks and firm monopoly (Kirsten and Sartorius 2002). Smallholders are likely to face more difficulties to perform under this practice as they require additional inputs and extension support (Key and Runsten 1999). So, it is not unfair to say that contract farming is more likely to be a contentious practice. A legal framework and proper management may aid in gaining benefit and protecting farmers' interests.

The Evolution of Contract Farming Act in India

The Agriculture Produce Marketing Committee (APMC) regulates all wholesale markets for agricultural produce in India. The agriculture market reforms in India saw the light of the day with the "Model Agriculture Produce Marketing (APMC) Act of 2003". It includes a provision that allows private sectors and cooperatives to be licensed to establish markets and contract farming (Chand 2012). Recently, the Union Agriculture Ministry established a "Model Contract Farming Act Drafting Committee", to integrate farmers with agro-industries to ensure better price returns and reduce post-harvest losses and create job opportunities in rural areas. On 23rd December 2017, the committee drafted a promotional and facilitative Model Contract Farming Act, titled "Model Act, The——-State/UT Agriculture Produce and Livestock Contract Farming (Promotion & Facilitation) Act, 2018," and requested states and UTs to kindly forward comments and views on the provisions within 15 days (Government of India 2018). Later, on 22nd May 2018, the GOI enacted "The — State /UT Agricultural Produce & Livestock Contract Farming and Services (Promotion & Facilitation) Act, 2018." (Government of India 2018). So far, Tamil Nadu is the only state that has implemented the contract farming law, which went into effect on October 1st, 2019 (Government of Tamil Nadu, 2019), while other states/UTs were contemplating it. Finally, the recent contentious bill passed in September 2020, and with the President's assent, it became the Act of the Parliament so that state/UTs are bound to implement it. This has rejuvenated the debates surroundings contract farming in India. This paper attempts to revisit the contract farming practice in India through a critically systematic review of previous empirical studies and critically evaluate the controversial CFA 2020 in a transparent manner.

The Methodology Applied to Review the Previous Studies

This paper is based on information and discussion from previous contract farming studies and the recently passed CFA 2020. A keyword search strategy on Scopus, Economic and Political Weekly (EPW), and Google Scholar have been followed to identify relevant research papers. The keywords searched were "contract", "contract farming", "income" "production", "India", "agriculture", "benefit", "limitation", "contract farming India". For final review, 26 papers were filtered, which mostly fulfil the paper's objectives building the critical assessment on the new Act.

Potential Benefits of Contract Farming Act, 2020

This section incorporates the contract farming issues raised in the previous empirical studies. And, if the promise is kept throughout the contract period, some provisions in the CFA 2020 might be protecting farmers and eventually benefit them.

Legal framework may protect from manipulation

Studies (e.g., Swain 2012; Narayanan 2014; Sharma 2016a; Mishra et al. 2018) shows that contract practices in India mostly follow the oral/verbal agreements without any legal backing fall short of protecting farmers' interests when either of the stakeholders violates the contract. A written agreement or signed contract backed by a legal framework (e.g., CFA 2020, page 2) not only protects each party's interests but also guarantees that both parties could take legal action if the contractual agreement is breached. Further, studies (e.g., Singh 2002a; Motkuri and Veslawatha 2005; Kumar and Kumar 2008; Hiremath and Kadam 2013; Dhanwantri and Bhalla 2014; Rana et al. 2014) find sponsors quite often taking advantage of oral/verbal contracts and tend to slightly increase the quality norms in an attempt to reject the farm produce and sometimes make payment delays. Thus, written agreement and specification of contract terms and conditions, such as quality, quantity, delivery time, payment (specified in the CFA 2020), will undoubtedly protect farmers from sponsor manipulation and rejection.

Inputs and price support

Further, providing farm services to farmers (more helpful for resource-poor farmers) and its specification during the agreement shall secure those services (inputs, extension, management, so forth), and farmers might be in better placed to know what inputs and support they may avail throughout the contract practice. Studies (e.g., Dileep et al. 2002; Khan 2010) find production costs much higher in contract farming, so input support (as mentioned in the CFA 2020) may help reduce transaction costs so input support (as mentioned in the CFA 2020) may help reduce transaction costs (e.g., Birthal et al. Gulati 2005) and farmers to participate in case intensive high-value crops cultivation which is in trends.

The price to be paid may be determined and mentioned in the agreement. In case of price variation, farmers will receive a guaranteed price and additional amount

Table 1 List of selected papers reviewed in this study (2000-2018)

S.N.	Author(s) & Year	States covered	Crops covered
1	Rangi and Sindhu 2000	Punjab	Tomato
2	Singh 2002a	Punjab	Vegetable crops
3	Singh 2002b	Punjab	Tomato, potato, and chilli.
4	Dileep et al. 2002	Haryana	Tomato
5	Tripathi et al. 2005	Haryana	Potato
6	Birthal et al. 2005	Punjab, Haryana, and Andhra Pradesh	Milk, vegetables and broiler.
7	Motkuri et al. 2005	Karnataka	Medicinal plants, gherkin, asparagus, baby corn, papaya, cucumbers.
8	Kumar 2006	Punjab	20 different crops and vegetables
9	Kumar and Kumar 2008	Karnataka	Gherkin, Baby corn, Paddy, Groundnut, Sunflower, Chilli, and Andhra PradeshRagi
10	Gauraha and Banafar 2009	Chhattisgarh	Menthe
11	Mallika et al. 2009	Karnataka	Gherkin and Chili
12	Khan 2010	Uttar Pradesh	Aromatic Basmati Rice
13	Swain 2011	Andhra Pradesh	Gherkin and Rice
14	Trebbin and Hassler 2012	Maharashtra	Mango and Cashew nuts
15	Hiremath and Kadam 2013	Karnataka	Medical Plants
16	Narayanan 2014	Tamil Nadu	Gherkins, papaya, marigold and broiler.
17	Dhanwantri and Bhalla 2014	Punjab	Tomato and Basmati rice
18	Rana et al. 2014	Karnataka	Potato
19	Pandit et al. 2015	West Bengal	Potato
20	Sharma 2016a	Punjab	Potato and Basmati rice.
21	Sharma, 2016b	Punjab	Tomato
22	Dutta et al. 2016	West Bengal	Potato
23	Sarkar 2017	West Bengal	Potato
24	Vicol 2017	Maharashtra	Potato
25	Mishra et al. 2018	Punjab, Haryana, and Uttarakhand	Organic basmati rice (OBR).
26	Kumar et al. 2018	Maharashtra	Onion

Source Compiled by Author

as a bonus or premium to ensure the best value, and such price reference may be linked to a specified APMC yard or electronic trading and transition platform (e.g., CFA 2020, page 4). This price security may help protect farmers in price variation, and they may avail some additional amount in case of an upward price moment.

Although fixed-price, which is often offered in contract farming in India, could have mitigated output market risks. Studies (e.g., Kumar and Kumar 2008; Hiremath and Kadam 2013) show that sponsors, in some cases, make payments that are months late. The delayed payment may be fixed once the new Act goes into effect. In agreement, the Act binds the sponsors/buyers to specify the payment period/time and method, which should not be more than thirty days.

Small farmer participation through FPOs

Previous studies (e.g., Swain 2012; Narayanan 2014; Sharma 2016a; Mishra et al. 2018) have claimed that contract farming somehow errands resource-rich farmers while restricting the participation of resource-poor smallholders who genuinely need assistance.

As the Act has mentioned, the formation of Farmer Producer Organizations (FPOs) may provide aggregation-related services (e.g., CFA, page 5) that could assist smallholders in becoming a part of the contract farming practice. A study (Trebbin and Hassler 2012) highlights that farmers' integrity and leadership stand make contract farming more sustainable. So, the FPOs may strengthen small farmers' bargaining power and develop the local farmers' integrity and leadership.

Insurance coverage and bonus support

As mentioned in the Act, a farming agreement may be linked with insurance or credit instrument under any scheme of Central Government or State or any financial provider to ensure risk alleviation and flow of credit to farmer or sponsor or both parties (see, e.g., CFA 2020, page 5). Farmers will be protected from significant losses if any parties provide insurance against unexpected production losses due to natural disasters.

The price reference for an additional bonus or premium to ensure the best value may be linked to the prevailing prices in specified APMC yard or other suitable benchmark prices. This upkeep will have guaranteed a price, encourage farmers to participate in contract farming or high-value cultivation, which is in high demand.

Dispute settlement and transparency in term adjustment

Conventional thinking always insists to assume that when two different classes (in this context, influential corporate and weaker farmers) get involved in a production system, there is a high chance of manipulation or dispute by either party. From that sense, the new Act will provide a legal framework for the contract agreement and help dispute settlement amicably so that both parties continue to honour the contract terms even if a disagreement arises.

Sponsors would have no chance of land grabbing because they are prohibited from acquiring ownership rights or making permanent changes to a farmer's land or premises. However, the Act will allow and may permit a chance for alteration or termination after entering into agreements, but mutual consent must be taken in such cases.

From the preceding discussion, it is clear that contract farmers in India have faced numerous challenges, a few of which might be resolved once the new Act comes into force. Though, the Act is not without flaws and shortcomings. Policymakers failed to address many practical issues that contract farmers face across the country.

The Drawback of Contract Farming Act, 2020

The government anticipates that the marketing reforms (as expected, the Act will allow more private sectors in agriculture) will make room for more merchants and increase competition, thereby limiting firm monopolies. But, *do the marketing reforms assist farmers in obtaining better prices?* Having more buyers does not necessarily guarantee a better price—bargaining and bargaining power also matter. In addition, the following section critically highlights some shortcomings of the new Act in comparison to issues and concerns raised by previous empirical studies. Thus the major shortcomings of the Act are as follows:

Lack of method determining price

Studies (e.g., Singh 2002b; Mallika et al. 2009) highlighted that farmers wish to allow more sponsors to restrict firm monopoly to get a better price. Although the new Act states that methods for determining such guaranteed price or additional amount must be annexed to the contract agreement, it has not mentioned which method will be followed. Therefore, it is not unfair to say that sponsors may take the onus of setting the price. Whether farmers will carry a chance to negotiate for a better price from the powerful sponsor remains unanswered.

Apprehensions of input and government support

Studies (e.g., Singh 2002b; Tripathi 2005, Kumar 2006; Pandit et al. 2015; Dutta et al. 2016; Sarkar 2017) highlight that sponsors often provide partial inputs. However, farmers in contract farming are required to produce a quality harvest to avoid rejection over quality. Furthermore, high-yield crop production and required quality always necessitate more fertilizer, pesticides, irrigation, and proper management, which may be unaffordable for smallholders. Although the new Act allows for farm services to be mentioned in agreements, this does not assure that farmers will receive those services; rather, it is more likely to depend on sponsors' capacity and good willingness. So, if sponsors do not provide inputs, deprived farmers most likely small farmers, possibly struggle to cope with capital-intensive contract farming practices. Even if sponsors provide fertilizer or pesticides, farmers must still secure electricity, irrigation, and transportation. The study finds (e.g., Gauraha and Banafar 2009) even though the contract practice was profitable, it did not last long due to a lack of infrastructure such as electricity, cold storage, road connectivity, etc. So, the provision of additional support like road, electricity, cold storage, support from the government could have made the Act more appealing.

Lack of production loss support

Although the Act mentioned natural disasters or disease outbreaks that are unavoidable and beyond the producers' control, they may be protected by insurance (see, e.g., CFA 2020, page 5), this Act ignored production loss that may be caused by low soil productivity and poor management. In addition, the Act ignored environmental sustainability, no mention about the use of pesticides, environmental degradation, soil management. Even though the study fund (e.g., Swain 2011) in such cases, the sponsor prefers to move to a new and better endowment area.

Insecurity of small farmers' participation

Registration of FPOs may help to join small farmers, but FPOs are unevenly distributed, and registration costs are too high. Studies (e.g., Rangi and Sindhu 2000; Singh 2002a; Swain 2011; Dhanwantri and Bhalla 2014; Sharma 2016b; Vicol 2017) highlighted that sponsor are selective and biased towards farmers as they often exclude smallholders and resource-poor farmers. So, the new Act may fall short of solving constraints that prevent small farmers from fully participating in market-oriented farming.

Lack of food security and environmental sustainability concerns

Contract farming practice typically involves so-called high-value crops, commercial, cash, or export crops, and commodities, the selection of which is more often determined by market demand and the interest of sponsors. The previous studies reveal (all the reviewed studies) in India contract farming involves largely in vegetable and fruits crops such as tomato, potato, chilli, medical plants, baby corn, papaya, cucumbers, gherkin, paddy (mainly basmati rice), groundnuts, sunflower, ragi, mentha, mango, cashew nuts, marigold, and onion. In a few cases, also arranged for the farming of milk and broilers in the country. The selection of such crops may impact crop diversity, agroecology, and the agriculture away from food grains may shift toward concentrations of non-food crops in particular and cash or export crops and specialization in general. One long-term effect of this farming may eventually weaken the country's food security.

Recommendation for Amendment of the Act

Since the Parliament passed the Acts, the country has seen widespread farmer protests against the new laws. Later in January 2021, in its verdict on the petition against the farm laws and farmers' protest, the SC set up a four-member committee and put on hold the three farm laws. However, the CFA 2020 appears to solve some of the issues that previous research indicates farmers are most likely facing in the country. Some flaws in the Act have been highlighted above, which the government can consider improving to make it more reliable, economically suitable, and environmentally sustainable.

Further government can also think on the most precious recommendation that has been made by the Rural

Infrastructure and Agro-Industries Division of FAO in 2012 on the title "Guiding principles for responsible contract farming operations" (FAO 2012).

The guidelines principals contain fourteen principles or provisions that must be followed to achieve the goal of contract farming. The principles include 'common purpose,' 'adherence to a legal framework' 'clear documentation,' 'readability of contract,' 'due attention and review,' 'disclosure,' 'transparency in price determination,' 'transparency and fairness in clauses relating to quality,' 'transparency and fairness in clauses related to input supply and use,' 'fairness in risk shearing,' 'prevention of unfair practices in buyer-farmer relations,' 'honouring contractual terms,' 'open dialogue,' 'clear mechanisms to settle disputes.'

By default, the CFA 2020 includes a few of those principles mentioned in the FAO guidelines. However, government can think of the other principles that could make the new Act more transparent and profitable. Such 'transparency in price determination' will provide bargaining power to obtain a better price for produce. The 'transparency and fairness in quality clauses' and 'fairness in risk shearing' may make farming more efficient, particularly when it comes to natural disasters and production loss. The 'transparency and fairness in clauses related to input supply and use' would encourage resource-limited small farmers to join the contract and produce and maintain high-quality harvests. Finally, sponsors and farmers must be loyal to each other, and if the above recommendations government can have in this new Act, it may enhance contract farming a win-win situation for both parties.

Conclusion

Contract farming is not a new practice in India; it has existed for decades without the support of a specific legal framework. It is well documented that contract farming promotes crop diversification, production, income growth, job creation, and so on. Several flaws, however, have emerged, some of which have been highlighted in this paper. Many previous studies advocated establishing a legal framework for contract farming practices to reap the benefits of success eventually. A closer examination of the new Act reveals that the word "may" appears more frequently than the word "shall," and one can reasonably assume that the fairness of the contract rests with the sponsors. Overall, agriculture must remain in the hands of farmers rather than the corporate sector. Along with contract farming, states should consider encouraging group contracts with local NGOs and farming organizations, FPOs, and institutions to strengthen contractual relationships and make them more durable and fair, and small farmers should most likely participate in this practice.

Also, before signing, the sponsors/buyers should allow enough time for the farmers to review the draft agreement and seek legal or other advice. In order to determine price, quality, supply, and use inputs, there should be transparency and fairness. The price based on quality or the price and quality parameter should be mutually agreed upon in a transparent manner, with farmers permitted to bargain while the agreement is being finalized. If farmers require inputs, either sponsors or the government must supply them; otherwise, resource-poor small and marginal farmers may find it challenging to enter into the contract agreement. When the open market price goes up compared to the contract agreed price, sponsors can consider procuring on the open market price. This will make the Act a win-win framework for the farmer, e.g., in Punjab, contract farming partnership with *Markfed,* where it has signed an agreement with farmers if the open market price goes up, they would have to purchase it according to the current market prices, but if the open market goes down, farmers were bounded to get the contract price (e.g., Dhanwantri and Bhalla 2014).

Since the Act has been passed in Parliament amid the COVID-19 pandemic and its going, it is challenging to make any empirical experiments on the Act. This paper attempts to critically analyses the Act and has suggested recommendation reviewing previous empirical studies. In a recently published book title "Contract Farming and Land Tenancy in India" (Kumar et al. 2020), authors argue contract farming has increased income, diversification while the cost of production is high and small farmers' benefits are relatively less. The book demanded that there should be a legal framework in contract farming practice to make the practice more reliable and transparent. Undoubtedly the new Act will be legal support for contract farming. It remains to be seen whether governments take those recommendations for Act amendments seriously, but this analysis may encourage one to look at the current practice of contract farming in India, especially in small farmer-dominated states.

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Options of promoting seeds of biofortified crops: a case study of Bihar

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Abstract Extracting from the policy documents related to the seed production and distribution, seed marketing and distribution networks, and the focussed group discussions and workshops this paper identifies options of promoting seeds of biofortified crops in the Indian state of Bihar. Accordingly, four plausible options, viz., established network of registered dealers (ENRD), fast forward network using truthfully labelled seeds (FFN), farmer to farmer exchange (FFC), and private players (PPC) are identified. While the ENRD is the most formalized, robust, and functional channel, FFN is frequently used and the most practical channel.

Keywords Biofortified, seeds, marketing, agribusiness

JEL Codes Q13, Q16, Q 19, M31

Nutrition remains an issue of prime concern in India. The country ranks 94 on the Global Hunger Index amongst 107 countries. India's 14% of the population is undernourished, and the stunting among children under five years of age is 37.4% (Press Trust of India 2020). According to the Global Nutrition Report, 2018, India tops the countries with stunted children (46.6 million) and accounts for 2 out of 3 child deaths due to malnutrition (Kaur 2019). The state of Bihar, home to more than 8.2% of India's population, is also home to a large number of malnourished children. It has the maximum number (48.35%) of stunted children under five years of age (Srivastava 2019) and is among the top three states in child deaths due to malnutrition (Kaur 2019).

Ensuring access to a diversified diet is the most sustainable solution against micronutrient deficiency; however, it is not an immediate feasible solution in developing countries as the poor lack purchasing power to buy diversified diets. There are more targeted interventions like food supplementation, industrial fortification, and nutrition education programs (Okello et al. 2019), but these have limitations for the countries like India where the number of people to be covered under such programs is too large, but resources are scarce. In India, staples dominate a typical diet, and the majority of the households although meet the energy requirement but not the micronutrient requirement. In this context, biofortification presents an alternative that not only can improve the nutritional content of staple foods but is a comparatively inexpensive, cost-effective and sustainable means of delivering more micronutrients to the poor (Bouis et al. 2014). Substituting biofortified cereal varieties for traditional ones has the potential to increase micronutrient intake meaningfully.

Biofortification, the term coined by the HarvestPlus Challenge Programme of the Consultative Group on International Agriculture Research (CGIAR), uses conventional breeding, transgenic techniques, and agronomic practices to enhance the micronutrient content in crops. The primary focus of biofortification is to increase iron, zinc, and beta-carotene contents in rice, wheat, maize, cassava, sweet potato, and beans.

Tying micro-nutrient to staple crops reduces vulnerability. When economic shocks occur, the poor tend to reduce their consumption of higher-value food commodities naturally rich in micronutrients. Further, with a one-time investment, the biofortified germplasm can be shared internationally, and the biofortified seeds can easily be reproduced and disseminated among poor farmers in marginal environments (Bouis and Saltzman 2017). Ex-ante cost-effectiveness studies have shown that for each country-crop-micronutrient combination, biofortification is a cost-effective intervention (Meenakshi et al. 2010).

Agriculture in Bihar

Bihar, the third most populous state with more than 8% of India's 1.3 billion people, is situated in the river plains of the basin of the Ganges. It is endowed with fertile alluvial soil with abundant water resources, especially groundwater, suitable for agriculture. Agriculture contributes 18% of the state GDP, which is higher than that of the national average. Similarly, the population employed in agriculture is around 80%, which is much higher than the national average (IBEF 2020). Although predominantly dependent on rains, agricultural development between 2005-06 and 2016-17 in Bihar presents a mixed picture. Agricultural grew 4.7% a year, higher than the national average of 3.6%. However, farmers in Bihar earn meagre Rs. 7,175 per month, i.e., Rs. 86,100 per annum (NABARD 2018).

Agriculture in Bihar is dominated by cereals —79% of the gross cropped area. Rice and wheat occupy 70% of the gross cropped area. However, their productivity is low (rice 1,530 kg/ha, wheat 2,346 kg/ha). Bihar's seed replacement rates (SRR) for crops like paddy and wheat have respectively increased to 42 and 31% in 2016-17 from as low as 11 and 12 % in 2005-06. Bihar needs biofortified crops early to take overcome the problem of malnutrition. The challenge before the state is twofold: first, it expects to feed its every citizen stomach full, and the next, it should ensure nutrition to all the people. Biofortified crops, particularly rice and wheat, present a viable option. To do so, the multiplication and distribution of seeds of biofortified crops is the foremost priority. Like any other state, in Bihar, both the government and privately-owned agencies are involved in the multiplication and distribution of seeds. Considering the nature of the biofortified crops and their popularity, the state agriculture policy, and the existing market, it is necessary to identify plausible options to promote biofortified seeds. This paper aims at (i) examining the existing seed policy of the state, (ii) studying the channels of seed production and distribution, and (iii) evaluate the best possible option for the promotion of biofortified crops in the state.

Methodology

The study was conducted in three phases. The first phase included a detailed analysis of the existing policies on seed production and seed distribution in the state. The second phase consisted of personal meetings and group discussions with different stakeholders including farmers, government agencies, representatives of seed industry representatives and NGOs (working in the field of health, food security, and nutrition), bureaucrats, agricultural scientists, and extension agents. The personal meetings were held for eliciting opinions of the stakeholders, whereas the group discussions helped to validate these leading to the development of a common understanding of the subject. The analysis of the first and second phases resulted in draft policy recommendations, which in turn was shared and discussed in a half day-long workshop (the third phase) of stakeholders.

Results and discussion

State policy and distribution

There has been a close association between agriculture policy followed in the country and the magnitude and sources of output growth. The positive impacts of seed policy reforms on agriculture across the countries are now established and have been well documented. The Indian seed industry has evolved from a system of state-owned seed enterprises, public research centres and government regulatory agencies into a system that includes highly competitive foreign and domestic firms, rapidly expanding market opportunities, increasingly complex regulatory systems and a range of new opportunities (Kolady et al. 2012). Moreover, when the system becomes more diverse and with multiple players, the policy becomes consequential; however, it may be noted that policies cannot change the seed supply's fundamental technical and economic characteristics. Although in India, where the seed markets have been opened for private players, the government and state policies continue to play a decisive role. As a result of the successive policy changes, the Indian seed industry has witnessed increased participation of the private sector in the seed market. The Indian seed market was valued at US$ 4.9 billion in 202020 and is expected to grow at an annual rate of 6.8% During 2020 – 2026 (Mordor Intelligence 2021).

The impacts of seed policy reforms on agriculture are well documented (Kolady et al. 2012). Therefore, an effective strategy must be developed to ensure that farmers continue to grow crops for mass consumption and seeds. In India, varietal release, seed multiplication, and distribution are regulated mainly by the Seed Act, 1966. The Act ensures that the newly released variety is suitable for cultivation in an agro-climatic zone and is superior on physical attributes like yield, germination percentage, ability to withstand seasonal variations, required agronomical practices, and quality parameters like nutrient content and effect on the environment. However, the release of the variety does not guarantee that farmers will adopt it. Its adoption depends on its technical and economic feasibility. Besides core benefits which farmers evaluate based on attributes like yield, crop duration, and resistance to diseases, farmers' buying behaviour also depends on agro-economic potential, which is dependent on the cost of seeds, expected cost of growing the variety, and the price of the final output.

However, the actual adoption and cultivation of the new variety will depend on the willingness of farmers to replace the existing variety, ease in availability of seeds, and extension support. Further, we need to appreciate that in general, crops such as cereals with high sowing rates and relatively low crop values are difficult to commercialize, and more so the biofortified cereals when farmers can preserve to use and share a part of their output to reduce repeat purchases of costly seeds. Hence, the interest of the seed industry in the business of biofortified cereals is not expected to be very high.

Possible options to promote biofortified seed

There was a consensus among all the stakeholders that biofortification has enormous potential in addressing the nutritional deficiencies at a mass scale. The government representatives have a more favourable attitude about the nutrient-rich cereals and other food grains in overcoming micronutrient malnutrition. However, the most significant point emerging from our study is the lack of awareness among farmers and consumers regarding the efficacy of biofortified cereals and their regular consumption as staple foods. It emerged that the notified varieties which can give farmers a value for their money could be taken to all the farmers of all the villages through the government and private seed distribution networks. Bihar has a network of more than 500 registered seed dealers who assist in making the seeds available at the farmers' doorstep.

Established Network of Registered Dealers (ENRD)

The first possible solution evolving out of the study to enhance the outreach of the biofortified seed materializes through the formally established network of registered dealers. Bihar Rajya Beej Nigam Limited (BRBNL) serves as the nodal agency to make seeds available to the farmers through the respective government-approved networks. Both the agencies have their outlets across the states and have a network of registered dealers with the agency for seed marketing and distribution. Figure 1 represents the ENRD of seed marketing and distribution.

ENRD is an effective channel having an outreach up to the village level for seed distribution. However, ENRD will be effective only in the case of the certified seeds of the notified varieties. In the case, non-certified seed varieties, this network will not be able to support it.

In Bihar, the agencies like HarvestPlus can work faster to get the most appropriate variety notified either by the central or state government agencies. However, to quicken the process, the zinc-rich wheat varieties like

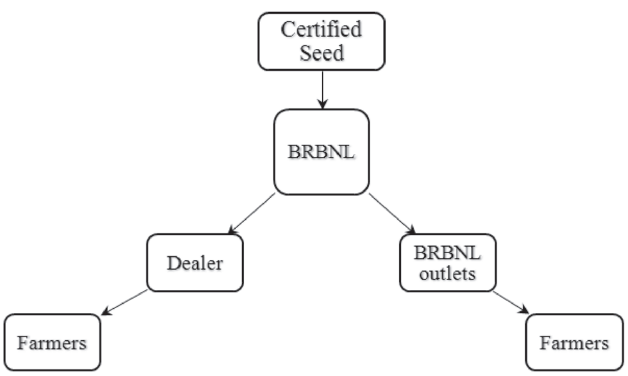

Figure 1 ENRD of seed distribution

BHU-35 and WB-02 have been found suitable during the initial field testing by the Bihar Agricultural University (BAU), Sabour. Once notified and certified, the varieties can be marketed through the formally established government-managed networks and dealers, besides being sold in the open market.

Fast Forward Network (FFN)

The other possible way of the faster seed distribution identified was to declare a suitable variety as 'Research Variety' for which research and field trials are in progress. The state-based agricultural universities and ICAR institutions have the authority to declare a variety as a 'Research Variety'. If declared, its seeds can be sold by the private seed marketing companies as Truthful Labelled (TL) seeds. Figure 2 represents the FFN of seed marketing and distribution.

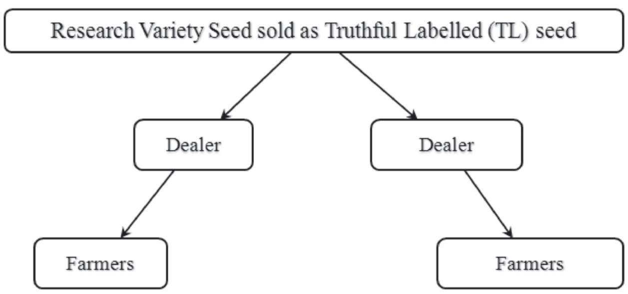

Figure 2 FFN of seed distribution

FFN is a popular way of marketing new seeds by private companies. Further, to meet the demand-supply gap of seed requirement, the central government allows states to promote TL seeds. Moreover, private companies are involved in a big way in the sales and marketing of TL seeds. However, in 2017 the state government, after finding irregularities by private companies in the name of TL varieties, decided to ban the sale of TL seeds. However, if the state government is convinced about a 'Research Variety', it can allow its sale and dissemination.

To promote and diffuse biofortified seeds faster and get them in the farmers' fields the TL can be a good option. This option is most useful and time-saving when a variety has not been notified, but the potential of the seed variety is beyond any doubt. Sensing the higher potential private companies usually lap the opportunity and sell seeds as the truthfully labelled seeds.

Farmer to Farmer Channel (FFC)

Since time immemorial, farmers have been saving a part of the produce for seed use and sharing with fellow farmers. The farmer-to-farmer seed distribution is promoted under the schemes "*Mukhyamantri Teevra Beej Vistar Yojana"* (MMTBVY) besides the centrally sponsored "*Beej Gaon*" (Seed Village) scheme. It is not possible to reach every farmer through the formal systems of seed distribution within a short duration. Hence, under MMTBVY and *Beej Gaon* scheme, the government makes foundation seeds available to the selected farmers. Under these schemes, the state government provides financial and technical incentives to the farmers for growing foundation and certified seeds and ensures the required quality standards by way of regular training, supervision, and monitoring of the farms of these registered farmers. The farmers can sell or share the seed with other farmers under this scheme. This scheme thus appears to be highly cost-effective with deeper penetration. Figure 3 depicts the FFC of seed distribution.

MMTBVY or by working on a similar model and replacing government with selected NGOs can intensify and hasten biofortified seed distribution through the NGO network to farmers and then farmers to farmers.

Private Players Channel (PPC)

It was found that seeds although not notified and certified for the states, do go in farmers' fields through private players. Agencies involved in such informal activities get seeds from states like Uttar Pradesh, Punjab, West Bengal, Haryana, Andhra Pradesh, Maharashtra and market them in Bihar. Rice varieties like *Saryu*-52 and *Nati Mansoori* (MTU7029) are still trendy in certain pockets in the state although these two varieties are more than fifteen years old.

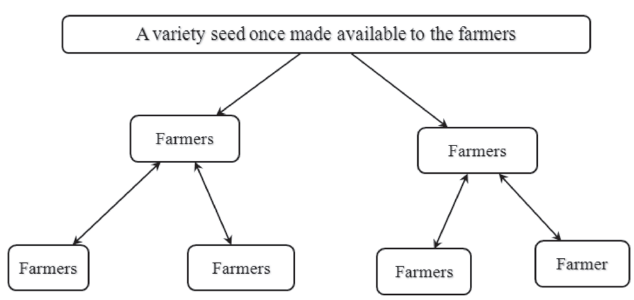

Figure 3 FFC of seed distribution

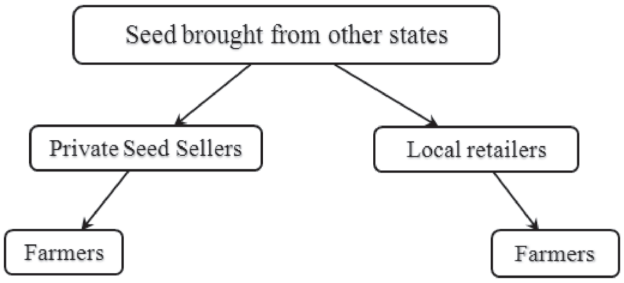

Figure 4 PPC of seed distribution

Although these varieties cannot be distributed in the state, seeds of these varieties enter the market and are adopted by the farmers. Further, many small private companies bring seeds of unknown brands and use the credibility of their local channel players to sell them. Figure 4 depicts the PPC of seed distribution. The significant point to be noted here is that the PPC is unauthorized, and hence, in the case of seed germination failure, the losses are borne mainly by the farmers or settled informally.

Evaluating options

SWOT analysis

To study the options in detail, it was decided to do the SWOT (Strength, Weakness, Opportunity, and Threat) analysis of these options.

While the ENRD is the most formalized, robust, and

Table 1 SWOT analysis ENRD

Strength	Weakness
Government-backed and sponsored – has credibility Established network of dealers across the state Government monitored Established credibility Can reach farmers with moderate speed	Only notified and certified seeds Will work only when govt. approves it Reports of delayed supply of seeds If the officer in charge is not convinced about biofortified seeds, one may not push the given variety vigorously. Besides seed distribution, we need to make our dealers/ retailers aware of the benefits of biofortified seeds.
Opportunity	Threat
Once variety get notified and certified, the network can be handy If govt. approves -the network can be used. BRBN has the infrastructure for quality seed handling and processing	Complete dependence on the government-led system is problematic because of limited infrastructure and human resources.

Table 2 SWOT analysis FFN

Strength	Weakness
Mainly private company/companies led effort – expected profit will drive companiesEstablished network of dealers across the state The credibility of the brand and the company/companies Can reach farmers with comparatively faster speed	The quality of seed is not entirely established Pushing by retailers mainly for profit May not recommend the standard procedure of cultivation if it is different from that for standard / typical varieties. Banned in Bihar
Opportunity	Threat
A potential variety can be introduced without wasting time in getting it notified. Once the variety gets notified and certified, the variety can move faster in the seed system. If notified and certified, the standard procedure of cultivation has already been established.	If seeds do meet the farmers' expectations, the credibility of companies and channel players (dealers/retailers) gets affected. Some not well-tested varieties may take this route without waiting for its certification.

Table 3 SWOT analysis FFC

Strength	Weakness
Led and run by farmersDoes not require a vast network Well tested variety is distributedBased on the traditional barter system Can be very effective and faster in a small cluster	Difficult to introduce new and improvised varieties Very difficult to spread any variety of pan-state in a short time because of its limited reach.
Opportunity	**Threat**
It can be used very effectively to reach faster across the state (as it is being used under the scheme MMTBVY, SV) if the government decides to spread the network. The usefulness of seeds can be tested very fast in every part of the state faster. Farmers take centre stage and can serve as capable extension workers to promote the seeds.	If the crop fails because of some other factor/s which is/are not related to the seed, the farmer will again be very hesitant about the variety.

Table 4 SWOT analysis PPC

Strength	Weakness
Has an informal but active network A cost-efficient system and know their customers (farmers) very well Responds to the needs of farmers very fast	It is an unauthorized system If the crop fails no one to take responsibility
Opportunity	**Threat**
The network can be used if required.	It can disappear any day.

functional system, the PPC is not worth considering, as, in a real sense, it is illegal. The FFN is not at a robust and ideal system but has been found frequently used in the Bihar seed market. It reduces the time taken in following the formal procedure of getting seeds notified and certified for the given area and gives the industry enough time to get the farmers' response. Also, the FFN system provides field-based feedback on the agro-economical potential of the seed. In Bihar, however, truthful labels are banned by the executive order (Singh 2017). The FFC is a traditional method and has been followed by the farmers for years. This method has been found useful also for crops, which are neither hybrid nor genetically modified. The state government has been able to make the best use of the strength of this system by using it under its popular schemes. FFC, although still not well established, appears to be a better option for the faster delivery of seeds of specialized crops like biofortified crops.

Usability analysis

Bihar is yet to notify and certify any biofortified variety. The state-based agriculture universities, based on their researches, have reported to found appropriate varieties that can be applied for notification and certification for the state. Further, considering the urgency of fortified food in Bihar, the seeds must be made available to the farmers fast and without any hassle to grow this crop. In this context, it was decided to do a usability analysis having feasibility and speed as the two parameters to suggest the most potent option for the state. A feasibility study was considered crucial because of the involvement of multiple agencies, including farmers and government agencies, the novelty of the product and the lack of explicit, delineable, and visible benefits of growing and consuming biofortified cereals. Speed was considered an essential factor as the issue (of hidden hunger) that biofortified cereals should address is urgent.

Table 5 Usability analysis of the options with feasibility and speed evaluation criteria

Possible options	ENRD	FIN	FFC	PPC	RKC
		Feasibility			
Existing rule / formal	XXXX		XXX		
Existing network	XXXX	XX	XXXX	XX	XX
Competency (HarvestPlus)	XXX	XXXX	X		XX
Financial implication (for HarvestPlus)	XX	X	XX		
		Speed			
To selected farmers (for seed)	XXX	XXXX	X	XX	XXXX
Among farmers (for the crop)	XXX	XXXX	XX	XX	XXXX

Note More number of X indicates a higher value.

Feasibility: Feasibility has been considered the possibility of the following option by the HarvestPlus in Bihar under the existing acts, rules, and functional structure of the seed system in the state. The feasibility has been studied based on (i) existing rules, (ii) Existing networks dealing with seed distribution, (iii) the agency's competency to manage/monitor, and (iv) financial implications mainly for implementing agency.

Speed: This refers to the time lag within which the seeds can be made available to every potential farmer and can be convinced and trained/ guided to grow fortified varieties. The speed has been studied in terms of (i) the speed with which the breeder/foundation seeds can reach farmers for seed production, and (ii) the speed with which these seeds get circulated among the farmers for cultivation.

Usability analysis, although did not spring any 'outstanding option,' did bring out relative strengths and limitations of various options. ENRD and FFN have maximum potential to meet the challenges. However, to be effective, it would be prudent to decide either in favour of one, which can give us better and early results or suggest some modification of either option without compromising its basic structure.

Conclusions

While the ENRD is the most formalized, robust, and functional system, FFN has been found frequently used in the Bihar seed market. The FFN reduces the time taken in getting seeds notified and certified for the given area and gives the industry enough time to get the farmers' response. It provides field-based feedback on the agro-economical potential of the seed. In Bihar, however, truthful labels are banned, but if presented well, the decision could be modified by the government to give biofortified seeds a chance. The FFC is a traditional method and has been followed by the farmers for years. This method has been found useful for crops, which are neither hybrid nor genetically modified. The state government has been able to make the best use of the strength of this system by using it under its popular schemes. Further, state seed policies and schemes to promote improved seed provide enough scope for promoting biofortified crops in the states. Field research findings on the yield of the varieties under test also present a very encouraging picture.

Bihar urgently needs a nutrition and food policy, which ensures the nutrition and food security of every citizen. Biofortified staples cereals have already been proven as one of the potential options. The government must ensure these cereals reach the needy people first and then to the entire population. The seed is the primary material required for the multiplication and spread of biofortified varieties. This paper suggests the most appropriate and feasible option of seed multiplication and spread of seeds in the state. Fortunately, state seed policies and schemes to promote improved seed provide enough scope for promoting biofortified crops in the states. However, if not pushed, it may take a very long time for biofortified cereals to enter into the state's existing seed chains and seed systems.

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Structure, vulnerabilities and policy for fish seed supply system in India

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Abstract Fish seed as a primary input determines the pace of aquaculture development. Traditionally, the fish seed was sourced from natural water bodies, and farmers faced several constraints like the mixed and ununiformed seed of non-targeted species, and uncertain supplies. The development of induced breeding technologies enabled the establishment of large numbers of hatcheries. Since then, remarkable growth has taken place in seed production. Yet, the seed sector suffers from several vulnerabilities like excessive centralisation, seasonal dependence, price fluctuations, and climate shocks. This paper suggests measures to improve governance and reduce vulnerabilities in creating a more resilient and efficient fish seed supply chain.

Keywords Fish seed, seed supply system, vulnerabilities, reliance, seed price, governance

JEL Codes D23, D49

Seed is the primary input in aquaculture. Historically, aquaculture in India started with the use of fish seed for stocking in confined waters. Until the 1970s, the natural rivers, streams and breeding grounds were the only sources of fish seed. A major shift in seed production happened with the artificial propagation of the seed in confined waters. The first breeding success in the carps in 1957 (Choudhury and Alikunhi,1957) initiated the spurt of aquaculture development activities, leading to a dramatic improvement in production and productivity of freshwater aquaculture. Over a period, the induced breeding technology spread throughout the country.

At present, fish seed production is carried out by small and marginal farmers with greater involvement of women. Despite such popularity of the practice, fish seed shortage (in quantity and quality) remains a matter of concern. This paper examines the production and trade of fish seed from the new institutional economics perspectives. It assesses seed production system, its vulnerabilities and suggest measures to improve it.

Materials and Methods

The study is based on data available at the national and state level on the production of the fish seed in India. The data available at the national and states provide information on the state-wise fry production which don't provide information on the production and trade of the spawn in the state. There is no available information on the state-wise volume of the spawn production and trade. State level information on the number of functional hatcheries available in published and unpublished literature are collected. In cases where such information is not available, estimates are prepared based on the discussion with officials and experts. This paper attempts to generate an estimate of deficit or surplus of the spawn in the states on the basis of level of production, seed requirements and available functional hatcheries in the states.

Primary data are collected through interview with the market functionaries, traders, office bearers of trades association from the major markets of seed like Naihati, Bankura, Rangia etc.The focused group discussion with farmers are made to delineate marketing system, vulnerabilities and other issues relating to the production and marketing of fish seed in India.

Results and Discussion

Evolution of seed production technology

Aquaculture in traditional ways are practised in small ponds, tanks and wetlands in West Bengal, Assam and Bihar and other coastal states of India to meet the growing demand for fish. Small water bodies exist either naturally or created artificially. The traditional aquaculture practices are improvements over the 'trap and hold' system, where stocking of seed in the small water bodies increase production and reduce uncertainties in the harvest. To stock these water bodies a large number of fish seeds are required leading to the development of the market for seed in eastern India.

In the past, a large number of the fishermen were involved in collecting naturally available seeds in rivers and rivulets in the deltaic regions. By the 1960s, the riverine collection of seed and transportation of it across the region was a thriving business in eastern India. Until the late 1970s, riverine seed collection was the main source of the seed of Indian Major Carps for aquaculture, contributing to 91.67% of the total fish seed production in 1964–1965. Bundhs (a special type of tank where riverine conditions were simulated during monsoon and carps bred) accounted for a major share of the fish seed until the 1980s (Basavraju 2007). During this period, research in inland fisheries focused on identification breeding grounds, development of effective and efficient ways of fish seed harvesting and establishment of fish seed marketing networks.

The research in seed production started with the exploration of the ways and means to simulate the natural riverine conditions for seed production. This led to the technology of the 'bundh breeding' in which the riverine conditions were simulated using a large expanse of the land and water with the efficacies remaining for a limited time. A breakthrough occurred in 1957 when the Cuttack station of Central Inland Fisheries Research Institute, Barrackpore (CIFRI) succeeded in breeding major carps in captivity through hyphophysation or inducing the breeding through injection of the pituitary gland extracts. Subsequently, Chinese carps were bred in 1962. With the advent of the technique of induced breeding of Indian major carps by Chaudhuri and Alikunhi (1957) and exotic carps by Alikunhi, Sukumaran and Parameshwaran (1963) through hypophysation, it became possible to obtain quality seed of major carps for aquaculture. This led to the development of dependable methods of pure seed production and which also opened for research in the genetic improvement programme. The breeding technology evolved through cloth happa, glass jar, circular hatchery with hatching response increased from 50% to 90%. Similarly, major research inputs were to improve fry raising from spawn with the improvement of survival from 5-10% to about 30-40% at present (Basavraju 2007). There were possibilities of improvement in the seed quality through genetic improvement programmes (Kumar, et al, 2008).

Concurrent research in the development of composite fish culture technology had demonstrated productivity of 6.0-9.0 per ha at research stations as well as in farmers' fields. The All Indian Coordinated Project on Composite Fish Culture and Seed Production experimented and demonstrated the technology across different agro-climatic zones during 1969-75. The experimental fish culture has been extended to cover large water bodies, varying from 1.48 ha to 2.15 ha under an operational research programme at Krishnanagar with net production of around 2514 – 4143 kg/ha/year (CIFRI 1979a). The Government of West Bengal adopted the technology on large scale and demonstrated gross production of 4.5 to 5.5 tons/ha in 1973-74 which was a quantum jump compared to the reported productivity of 600 kg/ha in the ponds through traditional methods of production. These technologies with modifications and adaptations were adopted across the country (CIFRI 1979b). The enhanced aquaculture productivity with the popularisation of the fish culture technologies created a high and sustained demand for fish seed in the country.

At present, not less than 2500 carp hatcheries are operational in India producing about 52,170 million fry (DAHD&F 2020). In the past four decades, enhancing the availability of quality seed has been a priority. The establishment of a hatchery and nursery is the primary strategy to make seeds available.

Seed production system

The seed production system in aquaculture is organised primarily as a three-stage system. In the first stage, the spawn is produced from broodstock in the hatchery

(hatchery operation), in the second stage spawn are raised to fry in about 3 weeks period (total cropping period including pond preparation and drying is about one month), in the third stage fry is grown for 2 to 3 month to attain the size of about 20 grams called fingerlings. Fingerlings are preferred by farmer as stocking materials as it reduces the time required to attain harvestable size, eases gauging quality standard and reduces mortality of the fish. The large hatcheries operators tend to integrate the first two-stage while large fish farmers integrate the last stage with the grow-out culture. Due to low cost, several small artisanal aquaculture farmers stock large quantities of the seed at the fry stage with the hope that a small percentage of seed will survive and grow to bigger sizes. Most of the large farmers prefer stocking a smaller number of large fingerlings or yearlings. The commercial operations are divided into clearly defined four stages of production from spawn to grow-out culture.

The seed production system is operated as a single integrated market in the country. Except for a few states (e.g., West Bengal and Assam), all of the states depend on interstate trade to meet the demand. Even in West Bengal and Assam, specific types of seeds (i.e., pangasius, magur and tilapia) are brought in from outside India. West Bengal is the hub and largest seed producer with around 1500 hatcheries. Two widely recognised and significant fish seed markets of the country viz, Naihati and Bankura, are functional in the state within a distance of around 200 kilometres catering to the need of the whole country.

The state of Assam and West Bengal start early breeding towards the end of February or 1st week of March reaching a peak by May and ending in June. Whereas in Odisha, Chhattisgarh, Jharkhand, Madhya Pradesh breeding starts in June and continues until August. In Andhra Pradesh July- August is the main season for breeding. Last year, there are reports of Tamil Nadu breeding Indian major carps in the month of December-January as a major technical breakthrough achieved with support from National Fisheries Development Board funded project operated by ICAR-Central Institute of Freshwater Aquaculture (Pers. Communication Dr. S. Nandi, Principal Scientist). Therefore, the early breeding of spawn in the states like West Bengal is the major source of spawn to all the seed growers across the country.

Trends in seed production

The estimated annual growth rate in the seed is 5.7% which is equivalent to the growth of inland fish production in India. The spawn production is estimated at 4 times that of fry production. Hence, the estimated spawn production is around 21000 crores (Table 1).

Table 1 Trends of fish seed production in India

Year	Fry (in million)	Estimated Spawn production (Million)
1973-74	409	1636
1978-79	912	3648
1984-85	5639	22556
1989-90	9691	38764
1994-95	14544	58176
1999-00	16589	66356
2004-05	20790	83160
2009-10	29313	117252
2014-15	39350	157400
2019-20	521706	2086824

Source DAHD&F, 2020

Spatial distribution of seed production

The fish seed hatcheries in the private sector started in 1978 with the first circular hatchery in West Bengal. Since then, several hatcheries are established in the state. A large number of hatcheries are concentrated around Naihati and Bankura as seed producing clusters. Similarly, a large number of small and medium-sized hatcheries are established in Assam and Uttar Pradesh. Therefore, these six states contribute a major share of the seed production i.e., 85% of the total seed production in India. West Bengal produced about 80% of the seed in 1985-86, but only 23.8% in 2017-18. Historically, West Bengal dominated the seed supply scenario in the country (Table 2, Figure 1).

Evolution of fish seed marketing

Prior to the induced breeding technology, the seeds were being collected and distributed from a few selected regions in West Bengal, Bihar, Assam and Odisha. West Bengal was the major source of fish seed and a large number of fishermen were involved in collecting seed from natural rivers. Most of the

Table 2 Fish seed production of selected states in million fry

Sl No	States	1985-86	1995-96	2005-06	2017-18
1	West Bengal	79.1	54.5	55.5	23.8
2	Jharkhand	0.0	0.0	0.1	19.8
3	Andhra Pradesh	3.6	4.7	3.9	16.9
4	Assam	0.4	17.0	14.6	15.3
5	Uttar Pradesh	1.9	3.6	4.9	5.2
6	Chhattisgarh	0.0	0.0	2.3	4.2
	Rest of India (RoI)	15.0	20.2	18.7	14.7
	Total	100.0	100.0	100.0	100.0

Source DAHD&F, 2020

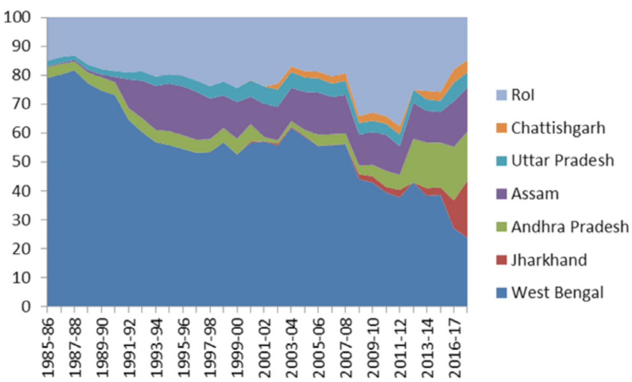

Figure 1 The trend of top six seed-producing states in India (%)

aquaculture areas were dependent on West Bengal for their seed requirements. The fish seed syndicate in Howrah was the first institution for coordination and development of the fish seed market in India established in early sixties. The government of India posted one officer in the syndicate to coordinate seed supply to various states in India during the sixties and seventies.

Immediately after the partition of India, a large number of fish breeding and seed collection centres located in East Pakistan were not available for the Indian market. Therefore, the syndicate provided incentives and support to collect and produce seed within the Indian side. The seed collectors on the Indian side of the border, with the availability of induced breeding in the later part of eighties, started establishing hatcheries to supply seed to the syndicate. The complementary development of seed production centres and seed market made West Bengal the dominant player in fish seed production and trade, as in 1985-86 around 80% of the seed demand in India was met by West Bengal. States like Andhra Pradesh, Assam, Rajasthan, and Uttar Pradesh have emerged as major seed producing states only since last decades. The fish seed markets in these states are not developed at the dimension of that of West Bengal. The large quantities of the seed in these states are still sold directly by the hatchery operators to the farmers or users to meet local demands.

Networks of fish seed vendors act as last mile connectivity to fish farmers across the country for fish seed. They provide seed at the door step of farmers by collecting seeds from markets or hatcheries. These vendors are connected with one of the seed production cluster in the country. For a small and marginal farmers, vendors are only source of seed in the seed stocking season (i.e. May-September).

In the areas where one or few isolated hatcheries operates, farmers directly buy seed (fry or fingerlings) from the hatcheries to meet their demand. In general, reach of such hatcheries through direct sale in limited to 200-500 farmers.

Market and marketing of fish seed

Hatchery operations in India are mostly carried out to sell spawn to seed growers or transport spawn to longer distances. Only a small proportion of the spawn are reared by hatcheries operators due to lack of sufficient rearing pond available at their disposal. A small scale hatchery produce about 2 million spawn in one cycle (one cycle can be taken at an interval of 1- 3 days as per the availability number of hatching pools. In case of one breeding pool and 3 hatching pools hatcheries can be technically operated every day) which require about 1 ha of the pond area. It require one month to grow fry (including pond preparation and growing period) and in a breeding season one pond can be used about 4 times. Hence, a small scale hatchery with 5 ha of the pond need to operate the hatchery only for 20 times but, it can operate about 90-120 cycle in a year if available rearing pond area is about 20-30 ha. Most of the hatcheries infrastructures remain underutilised due to lack of such rearing ponds. Hatcheries devise means like contractual arrangements for buy-back of fry from seed growers, annual contract to supply spawn in fixed quantities, shared seed rearing by bearing a part of the cost of production, creation of the nursery networks etc to develop arrangements to dispose spawn in large quantities. One of the prime objective of the hatcheries to sale as much spawn as possible within a short available breeding period of the year. Moreover, the hatcheries could be prepared and initiated into operation within a short time of 2-3 days and can deliver spawn to the buyer within 4-5 days of demand. Therefore, most of the hatcheries operate on-demand basis i.e. the spawn is produced on demand from the seed rearing farms. In an area where seed rearing ponds systems are not well developed and networked, productivity of hatchery operators reduces considerably.

Seed growers access spawn through 3 market channels, (1) The spawn bought by seed rearing groups either directly from the seed markets like Naihati or Ramsagar, (2) Vendors or suppliers buy from the seed market and deliver to the seed grower which involves long-distance transport by rail, air and road, and (3) direct purchase of the seed grower from hatcheries. Channel 1 & 2 is the dominant form of marketing system for hatcheries operators of West Bengal. Spawns are produced by specialised hatcheries in large quantities and large numbers of vendors engaged in long route transportation across the country. In channel 1 & 2 there are very limited interaction between hatcheries and seed grower. However, most of the states in India don't have organised market and hatcheries operators are directly connected with the seed grower in a quasi-market relationship as in channel 3. It is a relationship that is mixed of market exchange and long term clientele relationships. The prices are directly negotiated between seed growers and hatchery operators. This channel offers a lot of flexibility in gauging market demands and fulfilling the need of the market. This channel also offers flexibility in price and quantities as both parties negotiate as per requirements without much pressure of competitions.

The buyers of spawn are either a seed grower or fish farmers, buyer of fry or fingerlings are grow out fish farmers. Fish farmers choose to buy from market, vendors or hatchery operators which seems free and competitive. In a macro perspective, market system for fish seed seems competitive as large number of buyers and sellers simultaneously operated in market across country. But, the micro structure is not as free as it seems. The organised markets like Naihati, Bankura, Neelbagan, Rangia etc are controlled by trade associations. There are restrictions to entry to non-members to trade in these markets. The market practices, price fixing etc are being controlled by group of traders. At the decentralised level, one or few hatcheries operate in geographical locations. Hence, the market structure is either monopoly or oligopoly. Farmers are closely attached to one or few seed growers within a geographical domain. Hence, the fish seed market are not open and competitive. Excessive dependent on the farmers to one or few hatchery operators leads to price disadvantage to the farmers.

Fish seed trade

The fish seed is a nationally traded commodity in the form of spawn, fry and fingerlings. Spawns can be transported long distances with limited cost and hence, are transferred across the country in large quantities. The fry is also transported within short distances but in small numbers but the fingerlings are transported within the localities.

The major interstate trade for spawn is between state of West Bengal and RoI (Rest of India). In the state of West Bengal, out of total spawn production of 12,000 crores around 6000 crores are traded outside the state and reaching out to almost all parts of the country. The spawn is primarily transported by road through smaller vehicles within about 8-10 hours. Train is used to transport to nearby states within 15-18 hours from West Bengal. The air transport is used for transporting the high value fishes like catfish (Pangasius, pabda, magur, tilapia, ornamental fish, singhi, koi, etc) or ornamental fishes for smaller quantities.

The state of Assam is the next most important hatcheries cluster in the country. There are around 500 number of hatcheries in the state and supply seed to the most of the north-eastern part of the country. Each year, around 2000 crores of spawn are produced and additional 1000 crores are brought from West Bengal.

Similarly, there is significant amount of the regional trade. The spawns are supplied by Uttar Pradesh hatcheries to Rajasthan, Punjab, and Haryana. The spawn produced in Chhattisgarh are sent to Madhya Pradesh, Maharashtra and Odisha. The spawn and fry of Andhra Pradesh are flown to Karnataka, Tamilnadu, Kerala.

The summary of the trade is given in Table 3. Around 56% of the total spawn requirements of the all the states as given in the Table 3 are being imported from West Bengal. The dependence on the spawn from outside states varied from about 98.6% to 17%. Table shows dependence of the important aquaculture states on West Bengal to meet the demand of the spawn requirements.

Similarly, fry are also traded across the country to meet local demands. Every year around 1300 crores of fry are traded from one state to other state. West Bengal sent fry across the country while Assam sent fry to other north-eastern states. The state of Andhra Pradesh, Bihar, Gujarat, Kerala, Odisha, Punjab, and Gujarat also receive fry from other states. There are to and fro movement of fry across the state as estimated in Table 4.

Seasonality

Seasonal distribution of spawn production is presented in Table 5 which depicts the spawn production level of West Bengal and Rest of India by month-wise distribution. Out of estimated 20,000 crores of spawn around 12,000 crores are produced by West Bengal while Rest of India produces around 8,000 crores. All of these spawn produced are concentrated in April to

Table 3 The spawn supply by West Bengal to other states estimated for the year 2017-18

States	Imported spawn (Cr)	Share (%)	Total spawn requirements (Cr)	Share of requirements
Andhra Pradesh	655.4	9.3	3705.4	17.7
Assam	1152.0	16.3	3200.0	36.0
Jharkhand	4078.0	57.8	4134.0	98.6
Karnataka	59.2	0.8	99.2	59.7
Madhya Pradesh	286.9	4.1	446.9	64.2
Maharasthra	190.0	2.7	250.0	76.0
Punjab	71.2	1.0	111.2	64.0
Rajasthan	386.1	5.5	426.1	90.6
Tamilnadu	177.9	2.5	222.9	79.8
Total	7056.7	100.0	12595.7	56.0

Table 4 Interstate trade of fish fry in 2017-18

Interstate import		Interstate export	
States/UTs	Fry (cr)	States/UTs	Fry (cr)
Andhra Pradesh (Including Telengana)	554.3	Assam	412.5
Bihar	212.0	Jharkhand	287.7
Gujarat	36.0	West Bengal	585.1
Haryana	15.5	Total	1350.6
Karnataka	67.4		
Kerala	100.2		
Maharashtra	66.3		
Orissa	69.4		
Punjab	49.4		
Tamil Nadu	38.5		
Uttar Pradesh (Including Uttarakhand)	111.6		
Total	1320.8		

Table 5 Seasonal distribution of spawn production of carps (000 crores) in 2017-18

Months	West Bengal	Rest of India	Total	Cumulative (West Bengal in %)	Cumulative (Rest of India in %)	Cumulative (All India in %)
March	1	0.5	1.5	8.3	6.3	7.5
April	4	0.5	4.5	41.7	12.5	30.0
May	4	1.5	5.5	75.0	31.3	57.5
June	2	3.5	5.5	91.7	75.0	85.0
July	0.5	1.5	2.0	95.8	93.8	95.0
August	0.5	0.5	1.0	100.0	100.0	100.0
Total	12	8	20.0			

July months but provide major source for seed availability throughout the years.

As has been given in the Fig 2, the spawn production is concentred and depended on trade within short span of time for supplying seed throughout the year. Any disruption in the seed movement during this period affected overall availability across the country. As a case of such disruption in 2020 covid-19 lock down period March-May, 2020. Due to lack of movement seed in air, train and road, hatcheries in the West Bengal did not produce sufficient quantity of seed. The farmers across the country faced shortage of seed as vendors and traders were not able to supply seed to many parts of the country.

Cluster and Decentralized development

Since last four decades, aquaculture development progressed in every part of the country. National as well as state governments encourage farmers to grow fish in the available water bodies as well as land based activities though creation of ponds, tanks, water harvesting structures, farm ponds etc. Therefore, the demand for the fish seed is highly decentralised. On the other hand, the seed production system are developed in clusters and hatcheries are placed within a specified geographical area or cluster to take advantage of market and economics of scale. Within the specific clusters, it is easier to exchange knowledge, train and hire manpower, and transport products etc. Hence, seed production is being developed as successful business enterprises within specified clusters in the country. Some of the examples of such clusters are Ramsagar, Naihati in West Bengal, Khordha in Odisha, Rangia and Nilbagan in Assam etc.

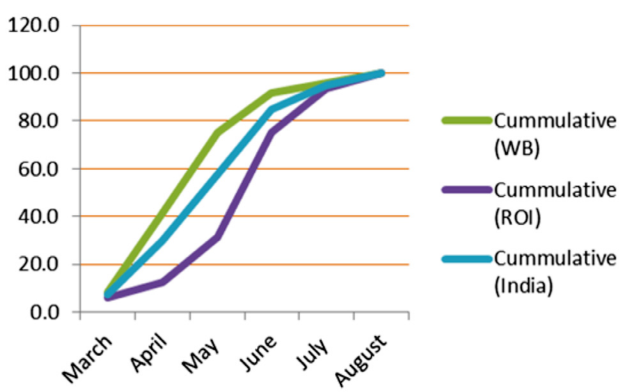

Figure 2 Cumulative distribution of spawn production

Long distance transport of seeds from the cluster add to the cost of seed to the farmers. There is a trade-off between cost of transportation and economics of scale for seed production in the clusters. Farmers prefer to reduce cost of transportation and opt for seed from nearby areas leading to more and more hatcheries development in a decentralised manner. The centralisation and decentralisation seed production system operate as a trade-off and determined through economic forces of cost and prices. With the present level of centralisation, it is disadvantage for the farmers to obtain seed from long distances since high cost due to mortality, transportation and quality reduction is borne by them.

Transaction cost in marketing

Fish seed is not a uniform commodity. It composed of seed of wide range of species, size and quality. Farmers demand and hence price of seed is specific to species, size and quality in the market. Quality of the seed is dependent on many factors like source of broodstock, feeding, genetic quality, breeding practices and nursing care etc. The buyer of the seed need to invest on time and energy in gathering information in availability, quality of the seed, price etc. Actual quality is difficult to ascertain from appearance. Since seeds are available within a short season, buyers need to take a quick decision on the quantity and quality of seed. Actual quality of seed can only be realised after substantial period of growing in farmers pond. Therefore, it is costly in identifying, measuring and enforcing contract in market transactions. High transaction cost is a major bottleneck is creation of competitive market for fish seed in India.

Vulnerabilities

The seed production system is vulnerable to fluctuation, shock and collapse. Some of the weaknesses and vulnerabilities are presented as below.

Seasonality of production

The technological progress so far have been successful in producing seed during monsoon season. With the efforts of farmers and scientists, breeding window has been widened for a period of March to September for carps. Beyond this period, the spawn production is not possible. Hence, there are scarcity of seed during most part of the year. Since aquaculture activities are carried out throughout year seed is demanded in whole year. But, seed is not available in the lean season, aquaculture operations need to make adjustments or ponds remains fallow during this period. The glut season followed by lean season makes facilities and large number of trained manpower unemployed. Seasonal availability of seed is a major vulnerability of the sector and challenge to increase productivity to meet rising demand for aquaculture products. The efforts to make seed available throughout the year is a way out to reduce this vulnerability.

Centralised production

The national demand for the fish seed is primarily met from the selected fish seed cluster in the country. These clusters dominate the market by transporting seed all across the country. There are losses of seed through mortalities and diseases during transportations leading to increase in the cost of seed. The solution to these problems lies in decentralised development of hatcheries across country. Typically, in a district with around 2500-3000 ha of aquaculture ponds, around 4-5 hatcheries would be able to supply adequate quantities of seed to the district. It would reduce the cost and loss of seed to the advantages of fish farmers.

Monopolistic market structure

Fish seed market is seller market and market is controlled by trader group or group of hatcheries or individual hatcheries as per market structure. Monopolistic competition is a predominantly occur when only few hatcheries operate within a specific geographical area. The terms of trade in fish seed is asymmetrically favoured the hatchery operators. This an inefficient system of market governance leading to poor market performance especially in delivering seed to farmers best quality at lower possible price is a major vulnerability of the seed production system in India.

Non-standardised weights and measurements

The seeds are being sold from one-day old hatchlings to yearlings. Size of fish seed varies with species, days of culture and condition of culture. The seeds are measured initially in volume (litres/ml), then weight (kg) and then count (number). The measures are not standardised. The cups (or *bati*) used in spawn trade vary from place to place. Due to non-standardization, farmers end up paying different prices for same commodities. It also hinders fair market integration across the country.

Price fluctuations

Seasonal price fluctuation is very high in fish seed. Price is dependent upon date of arrival, species, size and location. The price of carps spawn is as high as Rs 1800 per *bati* (25000 number) in March to about Rs 200 per *bati* in July-August every year. Similarly, the price of spawn is as high as Rs 800 per *bati* for catla to about Rs 200 per *bati* for rohu on the same day. These fluctuation is due to high degree of demand for early bred seed compared to late. Similarly, some of species preferred higher than other species.

Climate shocks

Climatic conditions determine success and failure of breeding operations. Most of the carps breed within a specific temperature range of 18-36^{o}C with matured condition of fish. In many years, there are climatic shocks especially with prevailing high temperature when fish is in mature condition. Under such conditions, there are often breeding failures. Similarly, low temperature affects maturity of brood fish and breeding performance. The fish seed production is vulnerable to prevailing high or very low temperatures.

Case of Disruption due to covid19 during 2020

There was a complete shutdown on the market and marketing of the spawn of West Bengal as traders were not able to operate during March-May of 2020. There was disruption in the road, rail an air connectivity. There was no scope for the interstate trade of spawn in the month of March, April and May as expected in normal year. Due to uncertainties of the market and transportation and non-availability of the labour, the largest hatcheries operators of west Bengal were not able to start the operations and resume spawn production.

As described previously, 70% of the spawn are produced by end of May and most of these spawns are transported to other states. The disruption reduced spawn in the country by about 30% due to lock down. Similar disruption has been affected across the state and net production loss of spawn till end of May was around 50%. A restricted breeding window for West Bengal and Assam at the end of May and hence recovery was very limited in West Bengal. The other states like Bihar, Uttar Pradesh, Odisha, Andhra Pradesh, and Chhattisgarh were partially affected. States other than West Bengal were not able to fully recover as hatchery capacity was limited and could not fully match loss of seed otherwise sourced from West Bengal.

Policy options and way forwards

Looking at the strength, weaknesses and vulnerabilities of the seed production system, following policy options and way forward is proposed.

- **Creation of competitive markets:** Creation of competitive market require increase in number of players in the market. When large number of buyers and sellers participate in the market, performance of market in delivery of fish seed shall improve. Competitive market requires increase in the suppliers of fish seed by establishment of more number of fish seed producers across country.
- **Participatory governance:** Till now, governance of market is dominated by the sellers. The trader association, group of hatchery operators determine the price and quality of fish seed. This asymmetric control can be improved upon by engaging fish farmers and consumers of fish seed in the governance. The market committee formed should be equally participated by sellers and buyers of seed. New measures for market reforms need to be carried out.
- **Year-round breeding**: Technology need be developed and applied to achieve year-round seed production especially of carps. Some the early trends in application of broodstock diet, environmental control. RAS etc has given encouraging results. Applications of such technologies are imperative to achieve all season availability of seed.
- **Standardisation of measures and weights**: Government needs to undertake measures to standardise system of measures of fish seed. The cups, weights etc used for measuring seed need to be standardised so that market development can takes place.
- **Regulation of market practices**: At present, the fish seed market is beyond ambit of government regulations. Appropriate regulations on the practices, qualities, price etc will help in improving performance of market system.
- **Decentralised development:** Decentralised development of fish seed production is key to holistic development of fish seed scenario in India. Excessive dependent on few clusters for seed is reducing efficiency in market performance. It is both costly and resulting low quality of seed due to long distance travel of fish seed. Establishment of large number of hatcheries across the country will reduce pressure on few cluster and improve market performance.
- **Seed certification:** Seed certification as per the guidelines developed by Government of India in 2010 (DAHD&F, 2010) is a key policy option to ensure production of quality seed in India. Measures needs to be taken at the state government level to fully implement the policy.

Conclusions

Performance of the fish seed sector can be measured in terms of effectiveness and efficiency in delivering best quality of seed at lower price across the country.

The performance is dependent upon techno-social structure of production and marketing. Technology determines efficiency of production, but effective delivery of fish seed at reasonable price is determined by market and quasi-market structure. The operation of market is dependent on the governance structure of market. It has been seen that the micro structure of the fish seed is not perfectly competitive. Traders association, group of hatchery operators, individual hatcheries within geographical regions are three main types of governance mechanisms of fish seed market in India. These lead to higher price of fish seed, high degree of price fluctuations and net loss to the fish farmers across the countries. Typical market structure creates vulnerability of fish seed supply system for very high fluctuations of price, delivery of bad quality seed at higher prices, seasonal glut and scarcity, climatic shock etc. There is need for change in the governance structure and socio-economic conditions under which fish seed marketing system operates to make it less vulnerable. Some of the measures for developing robust marketing system are decentralised development, creation of regulatory framework, seed certification, participatory market governance, etc.

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ABSTRACTS

Status of transformation in the agricultural sector of Odisha

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The paper has examined the changes that occurred in the agricultural sector during past decades, especially the changes in the cropping pattern and fertilizer uses and their effect on the economy. The study has found continuous fluctuation in agricultural growth but has a higher resilience. A strong positive association between fluctuations in the crops sub-sector (crop production and income) and overall variation in agriculture's share in gross state value added has been observed. Crop diversification should be kept in attention to a greater extent which could transform the farmers relying solely on crop specialization. The paper has also entailed various suggestions for a better transformation that could be achieved in the agricultural sector.

Sustainability of agriculture sector and food and farm subsidy in India: Issues and policy implications

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Along with a steady rise in agricultural subsidy over the last four decades, there has been a substantial rise in production due to higher capacity utilization of existing units or by the creation of new capacities. In the case of inputs, the rise in subsidy outgo is matched with a significant increase in indigenous production of fertilizer and its consumption. However, the increased use of fertilizers in India is accompanied by the disproportionate use of indigenously produced urea since other fertilizers are mainly imported. The major problem with input subsidies is that they lead to reduced public investment in agriculture on account of the erosion of investable resources and wasteful use of scarce resources, apart from causing other harmful effects like intensive use of inputs leading to reduced productivity, reduced employment elasticity of output substitution of capital for labour, and lowering of the water table. Further, though the major beneficiaries of fertilizer subsidy are the large farmers who mainly cultivate water-intensive crops, the issue of concern is the real beneficiary of fertilizer subsidy since the benefit goes to both the fertilizer industry as well as farmers. Another issue is the delivery of fertilizer subsidy, which should be directly given to the farmers and not through priority allocation of natural gas to fertilizer units. The concept of the Direct Benefit Transfer (DBT) system in fertilizers introduced by the Government in October 2016 and the formulation of policy relating to the implementation of Direct Cash Transfer (DCT) of fertilizer subsidy to farmers are yet to fully mature. The final decision on the implementation of DCT has not been taken so far. Apart from input, the Government continues to extend large amounts of food subsidies, which is already well known for administrative inefficiency, corruption and wastage. Moreover, it is found that the outreach of food subsidy in India has been highly inadequate and concentrated more in the relatively developed and fewer poverty states than vice versa.

Does commercial banks credit to agriculture and industry can raise per capita net state domestic product of India? a regional panel data analysis

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Bank credit to agriculture and industry plays a pivotal role in economic growth. It may stimulate the capital accumulation and rate of saving that further induce economic growth. However, there is no unanimous opinion on the relationship between bank credit to agriculture and industry, and economic growth. An attempt has been made to investigate the role of bank credit to agriculture and industry, and capital outlay on the per capita net state domestic product of India. To investigate such a relationship this study uses panel data regression techniques on different regions of India using the data from statistical handbook on Indian Economy published by RBI. The study finds that the fixed effect model is better than the random effect model and expansion of commercial banks credit to agriculture significantly and positively influences the per capita net state domestic product. Banks credit to the industry and capital outlay are not playing any significant role in stimulating per capita net state domestic product in various regions of India.

Small farm mechanization: Need, policies of Central and State governments

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In Odisha, the small and marginal holdings constitute around 90% of the total landholdings, which is supposed to increase in the future. The small and marginal farmers are generally unable to afford large scale mechanization. Small farm tools and implements that are manually operated, animal operated or operated by small petroleum, electric or solar-powered engines are very much useful and affordable for this large group of farmers. These small implements need popularization and location-specific modification for gaining acceptance over the traditional types of machinery. Apart from this, these machines are useful for drudgery reduction and decrease in the cost of cultivation. A good number of improved bullock drawn and manually operated farm implements have been

developed for different field operations. There is huge scope for small farm mechanization mostly in the tribal-dominated hilly terrain-based districts of Odisha as well in India. It also has a positive impact on the socio-economic status of small and marginal farmers. This study revealed the need for small farm mechanization, its related policies and long-term benefits to be achieved by the farmers of the state for their socio-economic improvements.

Temporal economic impact of conservation agriculture on marginal farms in West Bengal India: An assessment with DID method

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Prototype agriculture is facing several socio-economic and environmental challenges regarding sustainable livelihood and food security particularly for marginal and small households in India. Widespread soil erosion, nutrient mining, depleting water tables, and eroding biodiversity are nowadays the major issues in the long run agricultural sustainability in the country. The present study attempts to evaluate the economic impact of conservation agriculture in West Bengal as an alternative solution to these issues. The study compares the overall economic change of system productivity and return-cost ratio under conservation agricultural farms with conventional farming using the Difference in Difference (DID) method of estimation. The results depicted that changes in conservation agriculture over conventional farms increased from 4945 kg ha^{-1} in 2019-20 to 8480 kg ha^{-1} in 2020-21 with an overall gain of 3535 kg ha^{-1} over two years. The overall change in system net returns an increase of Rs. 1, 09,105 from Conservation agriculture over conventional farms. Conservation agriculture has utilized less tillage, less inputs, less mechanization and less manpower. The estimated gain in system productivity due to conservation agriculture was 69.13%.

Impact of poverty alleviation schemes on rural and urban Self-Help Groups in Andhra Pradesh

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Group-based projects can form an effective tool for rural and urban development. This study analyses the impact of poverty alleviation schemes on rural and urban SHGs in Andhra Pradesh. Using multistage random sampling,

222 SHG members were interviewed from 20 SHGs (ten SHGs from rural and ten SHGs from the urban). Results demonstrated several direct and indirect benefits for rural and urban SHGs at different social strata. The study recommends considering the involvement of SHG members in planning and implementation of any programs to harness better outcomes and impact in both rural and urban areas.

Dairying is an effective instrument for livelihood security: A study in the rural-urban interface of Bengaluru.

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The study was carried out in the rural-urban interface of Bengaluru to address the rapid urbanization of rural areas surrounding Bengaluru urban. Data of 240 dairy samples, 120 non-dairy samples were also drawn from different layers of the south and north transect. Thus, the total sample size was 360. The results revealed that livelihood index value was higher among dairy sample households (0.99) than the non-dairy sample households (0.70). Among the dairy farmers, a higher livelihood security index was observed in transition (3.18 & 5.47) layers than rural (2.47 & 2.25) and urban (2.28 & 2.18) layers in North and South transects, respectively. Further, the distribution of income in the case of dairy sample households was found equal in the transition layer of the north transect (0.43) and the urban layer of the south transect (0.32) as indicated by lower Gini coefficients. In respect of non-dairy sample households, income distribution was more unfair in the transition layer (0.63) of the north transect and urban layer (0.54) of the south transect. However, better income distribution was observed in rural layers of both north (0.47) and south (0.39) transects. Income from dairying reduces income inequality among dairy farmers than non-dairy farmers.

Economical sustainability of tribal livelihood through integrated farming system in Bastar region

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The high risk due to uncertain and erratic rainfall, small and marginal landholdings, poor adoption of alternate land-use systems and traditional livestock husbandry limit the scope for commercialization of agriculture. Sometimes, conditions turn worst when rainfall goes below the margin and upland fields are left at mercy of god or left for free cattle grazing. Identification of the problem, planning of the technical programme, development

of the action plan, implementation of the technical programme, formation of Climate Risk Monitoring Committee are useful adaptation measures. With the intervention of backyard activities, cost of cultivation increased 32.54% and economical parameters like gross monetary return and net monetary return were increased by 22.53 and 30.01%, respectively. A set of soil and water conservation measures played important role in conserving natural resources. In this context, the cost of cultivation was increased by 21.82% and gross monetary return and net monetary return increased by 26.44% and 30.96%, respectively. The lowest increase was 17.86% in the cost of cultivation whereas the highest was with gross monetary return (26.45%) which exhibit 16.48% net monetary return after an intervention. Gross income increased by about 19.75% over without intervention and investment was increased with intervention by 18.12%.

Livelihood sustainability through landscape planning for rainfed farming system

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The research was conducted in a cluster of villages of the Bastar region of central India. The region is rainfed. The most important issue was lack of technical knowledge (98.24%) followed by upland utilization (97.06%), drought or moisture stress (96.48%) and marketing (96.42%). The rice-based double cropping system under gabhar situation with conventional tillage (2 passes of the country plough and sowing of seed) for field pea recorded higher yield (1823 kg/ha), net returns (Rs. 63812/ha), B: C ratio (3.48) and RWUE (3.41). Whereas, manual removal of weeds at 25 DAS was found to be effective in reducing weeds with significant grain yield (5390.58 kg/ha) consuming energy 314.09 MJ/ha. Sowing of ragi in between fruit plantation was recorded higher yield of 1912.03 kg/ha, 8088.54 Rs/ha net return, B:C ratio (1.62) along with2.59 rainwater use efficiency.

Assessing agri-preneurial skills of farm youth in the Odisha state of India

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The large-scale unemployment and rural farm distress have led to exit of youth from farming. The agripreneurship development which focuses on creating key business skills has emerged as a panacea to revitalize Indian agriculture.

The study aims to assess and understand the actual agripreneurial skills of farm youth engaged in agriprenurship. A total of 250 respondents were selected from five different districts. An exclusive composite index was developed to assess agripreneurial skills in which weights were assigned by principal component analysis. The overall mean value of agripreneurial skill index was found to be 0.083 ranging from 0.07 to 0.09. The findings indicate that the farm youth are deficient in skills like problem-solving, agri-logistic management and information seeking. Good infrastructure, greater extension outreach were significant in enhancing the skill level.

Agripreneurship: A study on the role, growth and opportunities for the agricultural development in India

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The main objective of the present study is to examine the long-term changes in rural employment trends and future growth, and adaptation of agripreneurship model to overcome basic challenges in Indian agriculture. The paper identifies the problems in harnessing the potentiality of rural entrepreneurship. It focuses on the major hurdles faced by entrepreneurs especially in the field of marketing their products, in availing other inputs and components like water supply, electricity, transport services, and credit facilities. The findings of the study may be used to suggest strategies and policies for the future development of India's rural economy.

Entrepreneurial behaviour of rural women in Jharsuguda and Cuttack districts of Odisha

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The study has investigated the entrepreneurial behaviour of rural women in the Jharsuguda and Cuttack districts of Odisha. Women SHG members possess moderate production efficiency, managerial ability and marketing knowledge. Under production efficiency, the maximum number of women entrepreneurs had fully acquired skills regarding the ability to exchange and share information with the same type of entrepreneurs and the ability to work with team spirit. Under managerial activity, most of the women are efficient in planning to utilize time effectively and source effectively. Participation in training and extension programmes helps them update their skills. Concerning market knowledge, most of the entrepreneurs had acquired the ability in creating and use storage and processing facilities, market trends on the price of both inputs and final products. The majority of women entrepreneurs expressed labour cost as the main constraint for the production

Heuristics as a way to understand the micro-level decision-making process: A case of sugarcane farmers

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The sugar sector in India is highly regulated and farmers are badly affected by state policies and highly distressed being trapped in the nexus between capitalists and politicians. The objective of this study was to identify the determinants of micro-level decisions of sugarcane farmers. Primary data was collected from sugarcane farmers using a structured questionnaire. The influential scores and heuristics are used to analyse the data. The major determinants were identified as the interest rate on credit, amount of land available for cultivation with the farmers, accessibility to formal credit sources and market, water availability with the farmer for crop cultivation, sugarcane price, expected yield from different varieties and expected profit from sugarcane. The heuristics analysis reveals that choice of crop, choice of variety, frequency of irrigation, choice of market and choice of credit source were categorised under representative heuristics. While the choice of the planting season, methods of irrigation and fertiliser application were under available heuristics. Allocation of area and harvesting pattern of sugarcane farmers will follow the anchoring heuristics method of the decision-making process. The findings of the study provide useful insights for the policymakers to know about the determinants of the decision-making process through heuristics for policy-making and extension workers to help sugarcane farmers and the industry.

Institutions of rural haats and marts- key to socio-economic empowerment: Evidence from Jharkhand

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The focus of agricultural policy in India has shifted from production to income augmentation as reflected in the avowed goal of doubling farmers' income by 2022. Towards this, marketing institutions assume importance. At the grassroots level, weekly Rural Haats and Marts are the first lines of marketing avenues for farmers which have the potential to improve the income of primary producers and farmers. However, lack of proper infrastructure, i.e., raised platforms with roof shades, pathways, lack of proper connectivity, inadequate drainage, lack of toilets, and proper hygiene are serious challenges resulting in the low level of economic and social exchange in such markets. Against this backdrop, the study was conducted in Jharkhand to assess the impact of infrastructure created in NABARD assisted rural Haats and Marts on the socio-economic conditions of rural people in the catchment areas. The study found that up-gradation of infrastructure in the sample rural Haats has led to an increase in the number of sellers and buyers, increase in income level of sellers, lower price for buyers, increased

level of social exchange among the buyers/sellers, and socio-economic empowerment of villagers including women. The study suggested more investments in such infrastructures in institutions like rural Haats and Marts and better convergence of similar such schemes by the public, private and non-government organizations for profound impact on primary producers, artisans and women SHG members in the long run.

Impact of farmer producer organizations on farm economy in Krishna district of Andhra Pradesh

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Farmers' organizations are inclusive of the poor and are charged to become a market outlet for smallholder farmers. This paper investigates the determinants and effects on farm income of group membership, using the sample of 120 smallholder producers in the Krishna District of Andhra Pradesh. A probit regression model was used as a selection equation to identify factors that influence group membership decisions by smallholder farmers. Since farmers are resource-poor and farmer organizations are constrained by various institutional, technical and investment constraints despite their potential, it is recommended that favourable policies should be geared toward smallholder agriculture to ensure the success of farmer producer organizations. Our results show that farmer groups can be an important institution for the transformation of smallholder farming, increasing productivity and incomes thereby reducing poverty.

Adoption and spread of custom service provisioning of mechanical transplanting in Odisha: A case study

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Mechanical transplanting in Odisha has been in vogue since early 2000 with government patronage. However, expansion of area under mechanical transplanting is very much restricted. The current study analyses the government initiatives in promoting and the economics of scope of enhancing mechanical transplanting in the state. Custom service providers are operating at a smaller scale, operating 1-2 machines with the area coverage being mostly in the range of 20-60 acres. The economics of rice transplanter use is generally favourable for smaller types of machinery. Investment in these machines can be recovered, even without subsidy, in less than

two years if farmers can expand the area to 100ac per year. Service providers can recover about 77% of their net payment within one year after receiving the subsidy. Thus, the subsidy plays an important role in encouraging more farmers to become service providers.

Do government programmes on farm mechanization benefit small and marginal farmers? Empirical analysis of custom hire centres in Karnataka

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Karnataka has launched several schemes to increase food production by enhancing productivity. Krishi Yantra Dhare is one such scheme launched to improve smallholders' access to farm mechanisation through custom hire centres (CHCs). Amongst several service providers, Shree Kshetra Dharmasthala Rural Development Programme (SKDRDP) has established the highest number with 164 CHCs in 25 districts. SKDRDP was selected to understand the utilization of farm types of equipment. The data was analyzed to find the frequency of utilization of the services by crop, equipment, activity, hours of utilization and income generated from renting. Medium landholders have utilized the highest renting services from CHCs at 839.95 hours, followed by smallholders at 779.05 hours. The utilization was the most for rotavator, followed by 5 tyne cultivator. Rental income from combine harvester was the highest at Rs. 2,15,950.

Custom hiring centres (CHCs) and the dream of mechanized farming in India – An evaluation

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Farm mechanization is one of the obligatory steps for transforming Indian agriculture. Keeping this point in view, the Government of India has taken several initiatives for the improvement of the farming system. Recently, Indian Government has introduced the Custom Hiring Centre project under the scheme of SMAM (Sub-Mission

on Agricultural Mechanization). This scheme is playing an important role for poor farmers who are unable to buy costly farm types of machinery. Under this scheme, small and marginal farmers can use farm types of machinery under the control of Custom Hiring Centre where they charge comparatively low rent for use of types of machinery. As the small and marginal holdings constitute 80 per cent of total agricultural land, the potential of Custom Hiring Centre (CHC) is quite effective. The main objective of this paper is to evaluate the role of CHCs to promote farm mechanization. Simple statistical tools, tables and bar diagram has been used to arrive at scientific conclusions.

Village secretariat *vis-a-vis* institutional innovation: Modus operandi for agricultural intensification in Andhra Pradesh

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Agricultural intensification provides employment opportunities, prevents migration and address the reverse migration in the aftermath of the sustained Covid-19 pandemic situation. This paper proposes a framework for village secretariat functionaries, a novel initiative of Government of Andhra, in building capacity to conduct PRA/RRA for database through Agricultural Intensification Kit including Agro Economic Survey, Scaling Up Proforma and Questionnaire For Village Level Functionaries and finally brainstorming through a series of district wise and Mandal wise workshops.

Self Help Group-backed agro-enterprises in Chhattisgarh: A case of marketing opportunities

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A Self- Help Group (SHG) is a financial intermediary committee usually composed of 10 to 20 local women between 18 to 40 years usually engaged in producing agro and allied food products. For such input-intensive products, the contribution of variable cost dominates in the price setting of final products to the tune of 60 to 75%. With such variable cost loading on final products, these SHGs were able to make a decent return of 1.5 to 1.6 times over the initial cost. Principle constraints faced by the SHGs in their marketing endeavour were lack of modern machinery, proper storage structure, marketing skill, company tie-up and competition with branded companies. Findings suggest intended use of mobile platforms for buyers and sellers, improved packaging and

grading standards to make products attractive, tie-ups with local super markets/e-commerce space to increase shelf presence. Setting up a self-service kiosk in porch colonies will not only enhance the sales of products but will also educate the buyers about the health benefits of such low processed locally sourced products.

Choice of credit sources of small and marginal farmers in western Tamil Nadu

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Small and marginal farmers lack access to credit from institutional sources. The study focused on the choice of credit sources of small and marginal tribal and non-tribal farmers in western Tamil Nadu. Primary data were collected through a stratified random sampling design. Multinomial logit models were used to measure the factors influencing the choice of credit. Private borrowing was higher (74%) in tribal non-SHG members and 64% in non-tribal non-members. Results indicate that education is positively related to access to BL-SHG microfinance and BL-SHG microfinance with co-operative banks. Agricultural training too has a positive and significant relationship with the adoption of BL-SHGs.

Impact assessment of seed village programme using the difference-in-difference approach

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The objective of this paper is to assess the impact of the seed village programme (SVP) on paddy production. The study was conducted during 2019-20 in three zones of the Telangana state where the seed village programme was being implemented. The research investigation used a difference-in-difference approach to assess the impact accrued to the beneficiaries. There was a 69%increase in the income of beneficiaries as compared to that of non-beneficiaries (5.63%). The age education, seed landholding and farming experience put together contributed 71.6% to the total variation in increased income. The difference-in-difference regression results showed that, with the introduction of the SVP, there was also an increase in the average income of beneficiaries by Rs.13032/season.

Economic performance of Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) implementation in rural India

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The present study compares the implementing efficiency level of the MGNREG scheme in different states/UT of India. The Findings revealed that Rajasthan, Madhya Pradesh and Andhra Pradesh recorded the highest percentage of households completing 100 days of employment. Recently the number of average person-days per household under MGNREGS was 50 days, the highest women person-days were recorded to about 54% and the average wages rate paid was Rs. 191 which is increased to Rs.200 wage rate per day per person while comparing the minimum agricultural wages to about Rs.300 per day. The efficiency of states in the implementation of the scheme was measured using Data envelopment analysis. Input oriented DEA model was used under the assumption of constant returns to scale (CRS). Nearly three states under the assumption of constant returns to scale were found to be efficient. Based on technical efficiency values Kerala, Tamil Nadu and Tripura, were considered as best performing states, whereas Jammu and Kashmir (Union territory), Arunachal Pradesh and Goa are the least performing states which imply effective and non-effective in better implementation across rural India.

Socio-economic development of Kalahandi farmers through training and demonstration programmes in pulses

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The present study was carried out at six blocks of the Kalahandi district of Odisha to know the yield gap between recommended practice and farmers' practice through different demonstration programmes. Pulses yields are very low due to multiple constraints. One of the major constraints is the non-adoption of recommended and improved technologies. Government organized demonstrations for black gram and pigeon pea to popularize improved crop management practices, viz., YMV resistant variety PU-31 and pod borer resistant PRG-176 of pigeon pea seed treatment, and integrated pest management practices like spaying of neem oil, and need-based pesticide application. The demonstrations were conducted in farmers' fields during Kharif 2018 and 2019. The effective gains were Rs. 13704/ha and Rs. 13272/ha from pigeon pea and black gram, respectively. The incremental cost-benefit ratio was 2.11 and 6.14 for pigeon pea and black gram, respectively.

Study of socio-economic profile and constraints of commercial seed growers in Khargone district of Madhya Pradesh, India

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An entrepreneur is an economic man, who strives to maximize his profits by innovations. He is a man with a will to act, to assume risk and to bring about a change through the organization of human efforts. They are people who novice, organise, manage and power the affairs of a project that combine the factors of manufacture to supply goods and work in any enterprise, as such, the development or underdevelopment of entrepreneurship in the country. All-round development of agriculture is possible with the effective exploitation of human as well as material resources. In our country, where human resources are found to be plenty, we can identify individuals in all segments of the population who have the requisite entrepreneurial skills. Presently, the development of farmers producing seeds has become the primary concern in the area of seed production. In this regard, the function played by businessperson also assumes greater importance. Information on the seed industry was compiled from enlightened experts in the seed industry, seed certification information from the Texas Section of Agriculture (obtained under the Open Records Act), and elaborate reviews of USDA Farm Services Agency data. Seed production area displaced with interior seed supplies, crop value, national farm programs (crop outlooks), and export demand.

Does the watershed development program verily influence farming: An assessment study in rainfed tracts of Tamil Nadu

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This study has conducted an impact assessment of the watershed development programmes in Tamil Nadu relying on biological, physical, social and economic indicators. The watershed development structures are found to be satisfactory and contributed to the additional storage capacity, rise in the water table and also prolonged the water availability, increasing the irrigation intensity and cropping intensity. These resulted in enhanced productivity. Even it produced a significant impact on groundwater recharge. The study suggests the development of water harvesting structures through private investment in farm and percolation ponds.

Farmers' perception on risk and management strategies in Mahanadi river basin in Odisha: an economic analysis

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Using primary data from the Mahanadi river basin in Odisha, the present study has examined the risk perceptions, management strategies and their relationship with farm and farmer characteristics. A total of 311 farmers were interviewed from three districts, namely Sonepur, Boudh and Kendrapada, which are in the upper (102), middle (106) and lower (103) regions of the Mahanadi river. Drought was perceived as the most important source of risk in the upper region, inadequate government support including crop insurance in the middle region and flood in the lower region. The important risk management strategies followed were varietal diversification in the upper region, and crop diversification in middle (mixed cropping) and lower regions. The result of multiple regression analysis showed that risk perception of the farmers of three regions is influenced by social groups, off-farm income, ratio of earning members to the household size, farm size, land ownership status and government support. The regression results of management strategies were almost similar.

Bayesian estimation approach for farmers' willingness to pay for irrigation tank maintenance: The case of irrigation tank in Tamil Nadu

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Non-market-based valuation methods, such as the contingent valuation method, emphasise the estimation of mean or median willingness to pay. This paper employs a Bayesian approach to estimate a quantile binary regression and WTP distribution in a contingent valuation framework. The findings suggest that interpreting technical non-market valuation studies using alternative quantiles framed in the supermajority notion provides a plausible interpretation. The majority of the farmers (44%) are willing to pay about Rupees 2000 to 4000 per year for the tank.

Impact of drip irrigation technology on input use and productivity of banana crop in Gujarat

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Improving water-use efficiency is important for intensifying and diversifying agriculture. Micro-irrigation has been recognized as one of the important strategies for doubling the farmers' income. The impact of drip method of irrigation (DMI) amongst the farmers of middle Gujarat particularly in banana which is a water-loving plant reflected in terms of resources saving, improved productivity and profitability, thus, improved their livelihood. The research was conducted in Anand and Vadodara districts by collecting data from 120 drip farms and 120 non-drip farms of bananas in 2018-19. Drip irrigation method had a significant impact on saving of inputs, i.e. labour (19.99 %), water (31.11 %), growth regulators (22.72 %), plant protection chemicals (22.30 %), fertilizers (13.23 %) and manures (7.78 %). The yield and net profit were found significantly higher, on drip farms over conventionally irrigated farms.

The economic impact of micro-irrigation scheme "Per Drop More Crop": a case of sugarcane, banana and cotton cultivation in Maharashtra

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This paper estimates the economic impact of the micro irrigation adoption scheme "Per Drop More Crop" of the Government of India for sugarcane, banana and cotton cultivation in selected districts of Maharashtra. Before-after comparison is adopted using the data collected from the pre-tested interview schedules from 116 drip irrigation adopters in Maharashtra. After drip irrigation adoption, farmers had higher yields, profits and saved water across three crops. Per hectare yield of banana, sugarcane, and cotton increased by 73%, 36% and 80% respectively. With drip irrigation, farmers were able to grow sample crops with higher intensity. Net returns for banana, sugarcane, and cotton increased by 202%,5237%, and 296% respectively. Farmers were able to recover the fixed cost of drip irrigation (after deducting subsidy) within the first year itself.

Role of micro-irrigation in enhancing the productivity of brinjal in Maharashtra

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Considering the fast decline of irrigation potential and increased demand for water from different sectors, drip and sprinkler methods of irrigation have been introduced to conserve the scarce water resources in India. Several studies have assessed the technical and economic feasibility of drip irrigation in several crops and have proven its potential to save water and energy and enhance crop yields. However, only a few studies have assessed its techno-economic potential in vegetable crops. This study examines the role of drip irrigation in enhancing brinjal production based on primary data collected from a sample of 60 farmers; 30 adopters of and 30 non-adopters from Pune and Satara districts of Maharashtra in 2017-18. A partial budgeting technique was used to compare technical and financial parameters associated with brinjal cultivation with and without drip irrigation. The findings indicate that besides savings in water (40%) and electricity (547 kWh/acre), drip irrigation reduces the use of fertilizers (29%), and enhances crop yield by 52%.

Analysing constraints in adoption of drip and conventional irrigation methods in banana orchards: A comparative study of south Gujarat region

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The adoption of the drip irrigation method among the farmers of south Gujarat in water-intensive crops like banana serves as a tool for judicious use of resources. However, this method has its limitations. The study found that the top three constraints in the case of drip irrigation method were a high initial investment, clogging of emitters due to water salinity and frequent damage of the system due to rodents and other animals. Similarly, in the case of conventional irrigation methods wastage of water, followed by high electricity usage and waterlogging were the major constraints identified.

Whether performances of tank irrigation endure Indian agriculture or not?

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Tanks have been an important source of irrigation and account for more than one-third of the total irrigated area in Andhra Pradesh, Karnataka and Tamil Nadu. The study investigated the multiple uses of different tanks system through the Total Value of Output (TVO) and Total Revenue Realization (TRR) approach and Markov chain analysis to analyse the shifts in the tank irrigation system. Tax revenue realized from social forestry is higher in rehabilitated and non-rehabilitated tanks because of the timber value and marketability of the product. The study concluded that dependency between canal and tank irrigated areas is more than any other source of irrigation.

Assessment of ecosystem services: the case of Eastern Yamuna canal

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Irrigation is a critical input in crop production. Canal irrigation, on account of uncertain supply, straggled behind groundwater irrigation. Besides, higher maintenance cost and lower recovery to government expenditure on major and medium irrigation projects are major impediments to make canal as an efficient irrigation source. This study quantifies ecosystem services delivered by the canal in its command area. In Eastern Yamuna Canal(EYC) command, government incurs Rs.757.28 million as working expenses annually and only 3.01% of it is recovered as canal water charges. Accounting all the key services of the canal in monetary terms, the result shows that EYC delivered services to the ecosystem in its command area worth Rs.1122.86 million, 48.27% higher than working expenses. So, in business as usual scenario, canal irrigation system, despite yielding low revenue it generates ecosystem services worth more than its working expenses. Under pragmatic scenario, if government ensures timely availability of canal water as per crop water requirement and collecting water charges equal to working expenses from water users, then too, it could be win-win situation for government and farmers.

Comparative economics of sprinkler and surface irrigation in Raipur district of Chhattisgarh

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An attempt has been made in the study to deal with comparative economics of sprinkler and surface irrigation in the Raipur district of Chhattisgarh. Primary data was collected from selected farmers through a personal interview method with the help of an interview schedule. The wheat crop was selected specifically for the study as it covered the maximum area under sprinkler irrigation. The cost of installation of the sprinkler system for 0.203-0.405 ha, 0.405-1 ha, 1.01– 2 ha and >2 ha worked out as Rs.15418, Rs. 25531, Rs 40722 and Rs. 48131 respectively. Whereas the cost of installation of tube well worked out to be Rs. 72,900. On sprinkler irrigated farms, the per hectare overall gross returns were higher Rs. 77,270.66 whereas on surface irrigated farms it was Rs.62781.66.

An assessment of recent legal initiatives for improving groundwater governance in PUNJAB

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Groundwater (GW) has steadily emerged as the major source of water in India, and it contributes nearly 62% in irrigation, 85% in rural water supply, and 45% in the urban water supply, as per the report presented by Central Ground Water Board in the year 2018. In Punjab, GW provides irrigation to more than 72% of the area under the rice-wheat cropping system, and it has played a crucial role in its emergence as the ‘granary of India’. But the area under rice, a water-guzzling crop grown during summer has increased from 3.90 lac hectares in 1970-71 to 31.03 lac hectares in 2018-19. The runaway growth of GW irrigation has also contributed to the depletion of the water table and is thereby posing a huge environmental challenge. In this paper, an attempt has been made to review the recent legal developments for GW governance and assess their effect on the GW situation in the State. However, the increasing stress on aquifers due to GW irrigation has been reduced to an acceptable degree by strengthening and enforcement of legal framework coupled with a set of incentives and disincentives for improving its efficiency. The implementation of The Punjab Preservation of Sub-soil Water Act 2009 has contributed to a reduction in the consumptive use of irrigation water by 413 litres per kg of production of rice due to a change in the crop calendar of rice and the following wheat. It is increasingly acknowledged that for effective GW governance in Punjab, science and policy for GW use need to ûank and complement the legal frameworks.

Land modification models for restoring degraded waterlogged sodic soil in canal irrigated Indo-Gangetic plain of India: A socio-economic evaluation

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Sharda Sahayak Canal irrigation in part of the Indo-Gangetic plain led to twin problems of waterlogging and sodic soil formation. Inadequate drainage and seepages from the canal resulted in a rise in the water table and upward movement of salts on the surface soil made the land highly alkaline (pH over 9). After realising benefits for some years, the negative externalities offset the positive impact which led to crop losses, estimated to the extent of 45 and 62% for rice and wheat yields. Land and water productivity diminished and caused severe loss of livelihoods for the farmers adjacent to the canal area. Efforts to restore such land through conventional methods of gypsum-based reclamation, intercept drainage through perforated pipelines and eucalyptus bio-drainage belt were not found successful. The innovative land modification models (LMM) were evolved to harvest and use the seepage water from the canal and demonstrated at farmers' fields. Land and water quality improved and multiple crops were possible to grow on this degraded land. Economic evaluation in terms of financial feasibility, socio-economic suitability and sustainability of LMM models were assessed. The break-even size of interventions of the models was 0.44 ha and 0.38 ha for crop-based and fish-based systems. The models can be a solution to techno-economically sustainable problems, challenged by socio-economic constraints to some extent, which can be addressed through policy initiative, have been suggested.

Soil resources information for sustaining farmer producer company

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Soil resources information can be used to predict or estimate the potentials and limitations of soils for many specific uses. A soil survey includes an important part of the information that is used to make workable plans for land management. Knowledge of the characteristics of the soil helps in determining the crop choices, irrigation scheduling, soil amendment needs, general drainage requirements, and crop management practices needed to maintain optimal soil conditions for plant growth. Soil Survey information is an important component of technology transfer. Misallocation of factors of production across heterogeneous production units is important in explaining differences in measured productivity across farms. To assess the role of soil information in minimizing fertilizer misallocation, we consider soil resources information and the package of practices for crops as a benchmark for comparing fertilizer requirements for each of diverse farm households. We calculate the fertilizer use deviation

from soil test-based fertilizer requirement and blanket recommendations as misallocation. This paper focused on identifying the land resources constraints and potential status of Nanjevanapura village in Udigala Horticultural Producers Company, Chamarajnagar district, Karnataka which was established in 2016 by the Department of Horticulture, Government of Karnataka. Keeping in view the objectives of FPO, an attempt was made to study land resources inventory and provide the land resources information for enhancing the efficiency in horticultural production. The extent of fertilizer misallocation in the cultivation of tomato crop across the farms shows that there is considerable scope for reducing the excess application of Rs-1095(ranging from Rs -180 to Rs -2170) and deficit application of Rs 808 (ranging from Rs320 to Rs 1350) per ha. This conclusively supports the argument for avoiding the cost of fertilizer misallocation besides its impact on soil fertility degradation. Thus, using soil information, it is possible to reduce the cost of cultivation, enhancing productivity and long-term sustainability of Farmers Producer Companies as they have to identify the production clusters and estimate the correct input requirements for production planning of FPO.

A stochastic frontier analysis of technical efficiency in rice production in the union territory of Puducherry

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This study estimates technical efficiency in *Kharif* paddy production using data collected from 951 farmers in 2019-20. Stochastic frontier production function was used to estimate the technical efficiency. Findings reveal a mean technical efficiency of 81.77, 80.92 and 79.97% in the Puducherry, Karaikal and Yanam districts, respectively. The cost of manures and fertilizer and the cost of seed material had a positive influence on paddy. The results suggest the need to improve the profitability and efficiency of paddy production.

Technical efficiency of shrimp production in India: a stochastic frontier production function approach

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Technical efficiency (TE) measures the ability of the farmers to obtain maximum output from a given combination of inputs. This paper aims to examine the determinants of technical efficiency (TE) in shrimp culture in Pulicat area of Tamil Nadu in India. A stochastic production frontier model to estimate technical efficiency was applied

to samples of intensive farms interviewed during 2019. The TE ranges between 0.16 to 0.99 with the mean technical efficiency of 0.9 and it implies that the shrimp farmers can reach full technical efficiency by reducing their input by another 10%. Findings revealed that less than 25% of the shrimp farmers sampled have technical efficiency scores less than 0.80. Feed and manure & chemicals have been found as important determinants of TE. Results indicated that experience, education, family size and risk-bearing ability have a significant impact on technical efficiency.

Estimating the total factor productivity change in northern India using non-parametric malmquist productivity index

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Total factor productivity change is found to be negative for the three top foodgrain producing states of northern India. The value of TFP is found to be equal to 0.987, i.e, -1.3%. The study identified the main component leading to a fall in TFP and found a lack of technical progress. The study suggests that the focus should be on developing technologies that will help the farmers to realize higher output employing the lesser amount of inputs.

Total factor productivity and supply-demand gap analysis of rice in sub-tropics of Jammu region of Jammu and Kashmir

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An investigation on total factor productivity and supply demand gap of rice in the Jammu and Kathua districts of J&K was conducted during the agricultural year 2018-19. The results regarding trends in productivity growth of the rice showed that efficiency change was one for the overall period whereas technical change and TFP change were more than one for 2016-2017 which is 1.044 with a mean of 0.953 for the overall period. After calculating the demand and supply in sampled rice farms, both districts were found to be in a surplus stage which was highest in the Jammu district (282033 kg). Based on secondary data, it was also found that Jammu, Samba and Kathua districts had surplus production of rice, while all other districts of Jammu are deficit.

Does the labour market in the peri-urban region has a gender-neutral structure? An explorative analysis

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Freedom to work in the wake of expanding opportunities is a fair choice in an egalitarian society. However, women who are conventionally identified as homemakers, are often faced with several constraints to enter into a paid job resulting in a gendered labour market. Even in the era of urbanization, the situation is not so different as evident from the depressing Female Work Participation Rates (FWPR). This study, hence, focuses on the nature of the gender gap in peri-urban areas of Hyderabad Metropolitan Region since peri-urban spaces capture changes better. Based on the census survey data, FWPR in the rural and urban fringes of peri-urban study locations were estimated. The study reveals that urban sprawl does not guarantee a working environment for men and women equally and women are either pushed out of the workforce or are rendered with marginal works. 'A gendered society in developing world' was pictured and occupational segregation was also observed in the study locations. It was also observed that decline in FWPR is more of a rural phenomenon and hence policies favouring rural women, giving due support to urban women are to be formulated. In short, the existence of a 'gender-neutral workspace' should no longer remain hearsay.

Determination and modelling input energy used in wheat production in India using artificial neural network

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The exorbitant dependence on energy inputs has been posing substantial economic and ecological threats to the prospects of Indian agriculture. This research aims to determine and model the input energy used in wheat production in India. Primary household data from 256 farmers were collected from 4 different districts of the western part of Uttar Pradesh state using structured questionnaires. On average energy consumption in wheat production was 29612.43 MJ/hectares, with urea (47%), diesel (31.5%) and electricity (9.8%) contributing most to the energy intake. ANN model was used to capture the behaviour of input energy using various farm inputs and socio-economic factors and was seen to outperform MLR modelling technique.

Estimating the resource use efficiency in the production of chickpea in the Bemetara district of Chhattisgarh

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The study is based on 225 respondents of various size groups viz., marginal, small, medium and large. The multistage stratified proportionate random sampling procedure was applied for the selection of respondents. Cobb-Douglass production function was applied for estimating resource use efficiency of chickpea cultivation. The included factors in the functional analysis were land, labour, fertilizer, irrigation, seed input and plant protection chemicals. These explained 79.40% variation in chickpea yield. MVP (Marginal Value Product) of all included factors was found more than unity, explaining that there is further scope of investment on these factors to realize optimum production.

Agricultural roadmaps and the sustainability of commercial crop profitability and enhanced farm income levels on smallholder farming in Bihar

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The paper aims to assess the impact of policy changes in Bihar for enhancing the farm profitability and income of smallholder farmers. The paper is based on an analysis of crop cultivation behaviour of 36 smallholder farmers for two time periods of 3 years each, i.e. 2014-15 to 2016-17 (period 1) and 2017-18 to 2019-20 (period 2) in Vaishali district. The smallholders who were following the conventional cropping pattern of rice-wheat earlier shifted to commercial cropping (brinjal, tobacco, flowers, vegetables) during period 1 by allocating 42% of the area to commercial crops under the influence of new policy initiatives. The main factors responsible for this shift was the need for cash flows on daily basis, the awareness creation with the opening of more fertilizers and pesticides sale points, and the easy availability of the leased-in land. The change towards commercial cropping resulted in higher profitability and farm income. The farm income generated was Rs.4.0 lakh per ha in period 1 and was 5.42 times more than under conventional farming in period 2. The casual labour absorption during this period was also quite high, 190 days per farm (317 days per ha) and the casual labour use was to the extent of 79.2% of the total labour requirement. The farm prices were lower than the declared MSPs except for the pulses. The same smallholders abandoned the commercial cropping to a greater extent in period 2. The main reasons responsible for shifting back to conventional cropping was the poor rainwater drainage on account of uplands and contiguous lowlands resulting in continuous flooding ranging from a week to a month-long period, and the very low prices of commercial vegetable crops during one year. To sustain the commercial cropping and higher

incomes, strengthening of market infrastructures like cold storages, agro-processing units, crop-based support services and market intelligence. Further, the village/block level drainage-cum-irrigation works need to be designed and massive investment is required to execute the ground-level works under qualified technical supervision and as a major inter-departmental project or an MGNREGA work for increasing farm income as well as non-farm employment in the area. Locally developed institutional mechanisms for organizing supplies of smallholders also need to be integrated with a formal mechanism like FPOs to reap the synergies in production and marketing.

Dwindling farm profitability in Punjab: issues and concerns

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The present study was undertaken to study the functioning of output markets and their effect on the erosion of farm profitability in Punjab. Majority of the farmers cultivated paddy (227 farmers) and wheat crops (300 farmers). Farmers did not consider the adoption of alternative crops as profitable due to non-existent public procurement of crops other than wheat and paddy. It was revealed that crop diversification cannot take place unless there is an alternate MSP- based procurement system in place. Punjab has achieved very high levels of productivity of crops especially paddy and wheat with intensive use of different inputs Agricultural production process in the state has become cost-intensive and farmers had to borrow credit at a high rate of interest to meet the farm expenses. Capital investments were required for the purchase of productive assets, deepening of tube wells, and replacement of centrifugal to submersible pumps. Besides, hefty amounts are required for the repair of machinery and equipment, thus squeezing the profitability of agriculture. Majority (97%)of the farmers reported that the income from farming was not adequate. Various coping strategies were undertaken by the households in the wake of economic risks faced viz. reduce household consumption expenditure, deferred social and family functions, borrowed money from input dealers at a higher rate of interest. A mere increase of MSP for crops alone would not guarantee better income to the farmers. Along with price incentives, concerted efforts are required to be taken to strengthen the non-price incentives such as the procurement system and market infrastructure for crops other than paddy and wheat which fits well in the diversification plan of the Government of Punjab. Further, educating the farmers about subsidiary occupations, providing loans at low rates of interest, creating sufficient non-farm employment opportunities, assured purchase of agricultural produce with effective minimum support prices of alternative crops and further subsidizing agricultural inputs can help in minimizing some of the existing problems of the farmers and thus increase their incomes.

Comparative economic analysis of aggregate crop revenue in Jabalpur and Katni districts of Madhya Pradesh

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This study decomposes the aggregate crop revenue of two districts of Madhya Pradesh i.e. Jabalpur and Katni, into the area, yield, price and cropping pattern effect by using Logarithmic Mean Divisia Index (LMDI), for a period from 2007-08 to 2016-17. The results indicate that yield effect was the predominant factor in Katni district and price effect in Jabalpur. However, the cropping pattern effect had a relatively negligible contribution in both districts. The study suggests further improving and stabilizing the yield of the crops and implementation of policies focused on improving the cropping pattern in the districts.

Status of profitable combinations of mixed farming system by small tribal farmers of western Madhya Pradesh

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Scheduled tribes population represents a heterogeneous group scattered in MP. Jhabua, Alirajpur and Dhar tribal districts are in western Madhya Pradesh. A total 250 tribal farmers (125 marginal (0.1 to 1 ha) and 125 small (1.01 to 2 ha) who follow a mixed farming system were selected from 25 heavily populated villages of 5 densely populated blocks (out of 13) of Dhar district. The primary data was collected using an interview schedule for the year 2018-19. A mixed farming system on a particular farm of marginal and small farmers under study determines the particular farm includes crop production in a cropping sequence with raising of livestock (Milch cow) during a year. Farming enterprises include crops production with dairying. In this system, a combination of one or more crops or cropping system are carefully chosen and animals are kept with greater dividends than a single crop. In agriculture, management practices are usually formulated for individual crops or crops growing in a sequence. However, farmers are cultivating different crops in different seasons based on their adaptability to a particular season, domestic need and profitability. Therefore, the economics was calculated in a view all the crops grown in a year in the sequence with the number of cows rearing by marginal and small farmers in the particular mixed farming system.

Opportunities for promoting energy-smart agri-food value chains in India

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Energy plays a vital role in the expansion of agri-food markets and trade by contributing to increased and diversified crop production as well as powering allied sectors across the value chain from land preparation, transportation and processing to consumption of agri-food products. Therefore, decoupling fossil fuel dependence in the agri-food value chain and adoption of cost-effective alternative energy-saving systems that use energy efficiently without compromising on product quality, can have a direct link to achieving several SDGs. Towards this end, this paper is an exploratory study that gauges the extent of energy-efficient interventions in the agri-food value chain. Firstly, at the macro level, elucidating global efforts, such as those studied by FAO and REEEP and emerging technologies that contextually help to highlight and draw parallels to national and state efforts initiatives and Indian agri-tech start-ups.

Economic and value chain analysis on cashew nut in Meghalaya: A policy perspective

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The study analyses the economics of cashew nut production and value chains in Meghalaya. The present study was undertaken with the sample of 120 cashew nut growers comprising of 60 small (1-2 ha), 40 medium (2-4 ha) and 20 large (> 4 ha) farmers from eight villages of Selsella and Dadenggiri CD Blocks of West Garo Hills district of Meghalaya. Moreover, a sample of 10 village traders, 10 retailers, 5 wholesalers, 3 pre-harvest contractors and 2 processors in each major marketing centre was randomly drawn. Cost C_2 was higher in the first year of cultivation because of establishment cost, and later on, its cost gradually increased due to labour. The Gross Farm Income (GFI) was found to increase from Rs.34,321 per ha in the fifth year to Rs.1,24,685 per ha in the year of the tenth year. The net farm income was found at Rs.104824 per ha in the tenth year of cashew nut cultivation. Moreover, the economic return analysis shows that cashew nut crops in West Garo Hills of Meghalaya are highly profitable and their profitability must be realized by the cashew farmers of the state. The highest cost incurred by the wholesaler (Rs.200/- per qtl) followed by village merchant (Rs.70/- per qtl of cashew nut) and processor (Rs.60/- per qtl). The cost incurred by the wholesaler (Rs.100/- per qtl) for cleaning and drying raw

cashew nut in West Garo Hills of Meghalaya. It was observed that cashew producers incurred the cost of value addition of raw cashew nut through cleaning and sun drying and made disposal of raw cashew nut to the village merchant and wholesaler in the study area. It is evident that apart from the economic importance of the cashew nut value chain, it has got greater potentiality in generative income and employment at the farm level. In the West Garo Hills, the cashew nut value chain needs the application of modern technology and proper management practices for better production and marketing. The study highlighted that the prospect of the cashew nut value chain in Meghalaya is bright as the trend of other traditional crop production in the potential areas is quite encouraging for organic cashew farming. There is enough scope of enhancing the organic produce of cashew nut.

Economics of marketing of cotton in Rayagada district of Odisha

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India, the world's largest cotton producer, grows cotton in 122 lakh ha (8.74% of the country's net sown area) and produces over 361 lakh bales of 170 kgs each. In Odisha, cotton is an upcoming crop. Many farmers in the western region, mainly from Rayagada, Bolangir, Kalahandi, Nabarangpur, and Nuapara districts, cultivate it as a cash crop. It is presently grown in 1.69 lakh ha, that is, 2.73% of the state's total cropped area and 5.8 % of the state's total highland under crop. Present production is 4.65 lakh bales of 170 kg each (1.38% of the country's production) and productivity is 495 kg/ha (98.80% of the country's productivity). The study was conducted in the Rayagada district of Odisha to estimate the price spread and marketing efficiency in the marketing of cotton through different channels. Primary data was collected through a pre-tested questionnaire and various analytical methods like marketing cost, marketing margin, price spread and marketing efficiency were used to analyse the data. The results revealed that Channel I (Producer-Village Trader-Ginner-Consumer) was the most preferred channel through which 80.91% of produce was sold. Return received by the producer was highest in Channel III (Rs. 5700) and price spread was highest in Channel I (Rs.2200) which indicated that with increased intermediaries and length of channel price spread increased and return received decreased. Marketing efficiency (3.83) was highest in Channel III (Producer-Ginner-Consumer).

Production and marketing status of maize crop in India

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The study has examined the performance of maize crops concerning area, production and yield in India along with the market integration status of major maize producing states. The study has covered the period from 1960 to 2019. The analysis has been conducted using Autoregressive integrated moving average (ARIMA), compound annual growth rate (CAGR), Johansen co-integration and Granger causality test. The results have depicted a continuous increase in area, production and yield of maize crops in India. The analysis of ACF & PACF of differenced series revealed that ARIMA (0,1,0) for the area, (2,1,3) for production and (2,1,1) for yield was the most suitable model for forecasting. The selected ARIMA model predicted an increase of 10.58 m ha, 35.65 MT and 3390.50 kg/ha increase in maize area, production and yield by 2025. The market integration status has shown that among three major maize producing states, the Punjab market showed unidirectional causality in price transmission with maize price of Madhya Pradesh market and Uttar Pradesh market. The policy intervention calls for strengthening the market intelligence wing in all markets along with the establishment of an online marketing system through computerization and networking.

Marketing issues of sugarcane in Punjab

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Sugarcane is one of the important commercial crops of Punjab. A survey of 200 cultivators regarding harvesting and transportation cost of sugarcane was undertaken. It was found that the harvesting of sugarcane was under a contractual labour system involving only male workers. The wage rate was found to be varying in the range of Rs. 50-60 per quintal. The total harvesting cost of sugarcane on the sample farms was estimated at Rs.15071 per acre. The transportation of sugarcane from farm gate to sugar mills was mechanized and tractor-trolley was the only mode of transportation. Loading was completely manual and loading charges were included in the contractual amount of harvesting. Total transportation cost on the sample farms was estimated at Rs.3479 per acre. The unloading system was mechanized and exclusively undertaken by sugar mills. Biased distribution of purchase slips by the sugar mills and prolonged waiting period in disposing of the crop was the main issues reported by the cultivators during the survey.

Marketing of tomato crop in Durg district of Chhattisgarh

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The present study analyses marketing of tomato crop in the Durg district of Chhattisgarh. For this 40 vegetable growers, and 10 village traders, wholesalers, retailers were selected. The data were collected with the help of a specially tested schedule by personal interview method. Three marketing networks have been established for the marketing of the main vegetables, which were Channel I :Producer' to Consumer, Channel II : from farmer' to Retailer;' and Retailer' to Consumer and Channel III : Producer to Wholesaler to Retailer to Consumer. The farmer's share of consumer's rupee was the largest in Channel I, followed by Channel II, and Channel III.

Innovative models operated for marketing of horticultural produces during COVID 19 lockdown

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A study was conducted to document the innovative models that were operated by formal and informal organizations to help the farmers/sellers to market their horticultural produces during lockdown period 1 of COVID 19 Pandemic, especially in and around Bengaluru City, Karnataka, India. This paper discusses in brief about 10 such models selected using snowball sampling procedure, operated by development departments (2), farmers producers organizations (FPOs) (2), voluntary associations (2) and private organizations/ players (4). This paper also brings about the monetary benefits realized by 75 such farmers/sellers, who benefitted through such models. Further, innovations adopted through these models towards organizing the marketing of farmers' produce also are discussed here. Based on the understanding of such models, a strategic model has been proposed for reference during similar situations by the stakeholders.

Proposed IABM (Integrated Agri-Business Model): A modified perspective of policy towards PPP in agri-business

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The paper reviews the background and the reasons for the present state of the agricultural-produce-processing-marketing chain where the 'risk-reward-equation' is not in favour of the farmer-producers. After reviewing, the PPP agri-business-models currently in vogue, the article proposes a modified model called IABM (Integrated Agribusiness Model) that could be beneficial to all the three agencies namely the corporates, the farming community and the government at the same time. The distinguishing features of the IABM from the PPP models tried out so far, are its suitability to the marginal and small farmers, creating skilled and semi-skilled employment opportunities, reduced dependence on climate & market, energy-self-sufficiency, excellent 360-degree linkages and most importantly, high regard for the sustainable & inclusive rural development with emphasis on women-empowerment.

Market integration and the law of one price: An exploration of the major onion markets of India

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Twisting prices of onion haunt not only the stakeholders but also the politicians since the 1990s. Being the most sensitive horticultural commodity, onion warrants special attention of the policymakers to take necessary remedial measures to curb the prices congenial for both producers as well as consumers. The present study silhouette extent of market integration and determine the presence of the law of one price across selected major onion markets of India. Weekly prices of onion from July 2019 to June 2021 has been considered for the analysis. Augmented Dickey-Fuller Statistics has been used to check for stationarity and order of integration followed by Johansen Co-integration test and granger causality. The findings revealed the presence of unit root and strong spatial integration across the selected markets.

Trend analysis and seasonal variability of price and market arrivals of tomato in West-Bengal

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The study has been conducted for observing the trend and seasonal variability of price and market arrival of tomatoes in five markets from five different markets of West Bengal. Seasonality analysis is done by the 12-month moving average(TMMA) decomposition method and trend analysis is done through the ordinary least square(OLS) method after de-seasonalizing the monthly data over 2013-2014 to 2018-19 period. Study reveals that price is more stable in Barasat and Bardhaman across the months compared to that of the remaining three markets, namely, Chakdah, Siliguri, and Diamond Harbour which have experienced large month to month fluctuation in prices of tomatoes; but there is no definite pattern has been found for variability in market arrival. Generally, seasonal indices for arrivals are higher in those months which fall under the harvesting or post-harvesting season of tomato whereas price-indices are lower these months. Including these months some markets (like Bardhaman, Chakdah, etc.) show higher arrival-indices also for some other months which discloses the fact about the farmers' expectancy on higher prices in near future. The positive significant arrival trend is observed only in the Diamond Harbour market whereas a positive price trend is recorded in all five markets with varying magnitude.

Machine learning techniques for predicting the price of brinjal in markets of Odisha

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Price forecasting of vegetables has important implications for farmers, traders as well as consumers. A timely and accurate forecast of price helps the farmers switch between alternative nearby markets to sell their products and get good prices. The farmers can use the information to make choices around the timing of marketing. Brinjal is one of the important vegetables consumed all over the country. For forecasting the price of agricultural commodities, several statistical models have been applied in past but those models have their limitations in terms of assumptions. Recently, Machine Learning (ML) techniques have been quite successful in modelling time series data. Though numerous empirical studies have shown that ML approaches outperform time series models in forecasting different financial assets, their application in forecasting vegetable prices in India is scarce. In the present investigation, an attempt has been made to apply efficient ML algorithms e.g. Generalized Neural Network (GRNN), Support Vector Regression (SVR), Random Forest (RF) and Gradient Boosting Machine (GBM) for

forecasting the wholesale price of Brinjal in major markets of Odisha. An empirical comparison of the predictive accuracies of different models with that of the usual autoregressive integrated moving average (ARIMA) model is carried out and it is observed that ML techniques particularly GRNN perform better.

India's agri trade story: Trends, comparative advantages and future perspective

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For India to be integrated into the global value chain, as envisaged in the Atma Nirbhar Bharat Mission, the agriculture sector in general and agriculture trade, in particular, will play a critical role. The paper attempts to lucidly present a picture of the trends and patterns in agricultural trade from 1991-2021. The paper also highlights the stellar performance of agriculture exports during 2020-21 despite the COVID-19 pandemic. The Revealed Comparative Advantage (RCA) Index and Trade Specialisation Coefficient (TSC) Index are used to know the trade advantage for agricultural commodities and the potential Indian agriculture exports. However, to achieve the target of expanding agri-exports to US$100 billion requires persistent efforts to create a brand value of agricultural exports, diversification of agri-products and reach out to new markets. This would require a revamping of agricultural value chains by fostering and nurturing Farmer Producer Organisations (FPOs), agri start-ups and agri-export clusters.

Production and exports during pre and post-National Horticulture Mission in India

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India stands second after China in the production of fruits comprising a 9.57 % share of the production of fruits to the world followed by Brazil, the USA, and Mexico. Change in production trends and export scenarios in pre and post-NHM was analyzed. Results highlighted that there was an increase in production trends of total fruits in the pre and post NHM period. This initiative acted as a table-turner in terms of an increase in the yield of the fruits. This led to an increase in the yield of mangoes, mangosteens, and guavas. It had played an important role in increasing the export in terms of quantity and value of fresh as well as processed fruits.

Export performance and competitiveness of fruits and vegetables from India

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The study examined the growth, instability and structural change in exports of major fruits and vegetables from India during the pre-NHM and post-periods. Time-series data for 24 years from 1993-94 to 2016-17 was used. Fruits and vegetables registered higher growth in productivity and production in post-NHM. Regarding exports, growth in quantity, value and unit value was high for grapes in post-NHM and growth in unit value was high for all major fruits in post-NHM. Mango pulp continued to be the largest processed item exported but the growth rate in export quantity, value and unit value declined in post-NHM. Among vegetables, growth in the export quantity of onions, potatoes and peas was high in the pre-NHM period. Markov chain analysis revealed that UAE was a stable market for the export of mango, oranges, papaya and peas; and Nepal was a stable export market for oranges, apple, onion and potato. India is losing its markets in some of its fruit and vegetable exports to other Asian competitors. Yield improvements would increase exports. Institutional initiatives like contract farming would help to improve the production and quality of potatoes and peas. Strategies for export promotion may be oriented towards stable markets. New markets may be explored to reduce trade risks in the long run.

New agriculture reforms in India in 2020: An exploration of the conditions for their successful implementation

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In 2020 the Government of India has enacted three landmark farm laws that are supposed to bring about considerable improvements in the lives of farmers in India. These Acts are related to the marketing of farmers' produce, contract farming with assured prices, and hoarding of agricultural produce. It is expected that if properly implemented it will immensely help augment farm production and income, attract investment and technology by providing essential freedom and incentives to the producers and traders of agricultural commodities both directly and indirectly. However, there has been tremendous opposition and agitation by farmers' associations especially in Punjab and Haryana demanding repeal of these Acts. Litigation is pending in the Supreme Court of India against the implementation of these Acts. The Central Government has suspended the execution of the laws for one and half years. Despite agitation by some sections of farmers, the study finds that these Acts will bring beneficial changes to the lives of the stakeholders and, therefore, need to be implemented by plugging the loopholes and by taking the key players into confidence to achieve the desired beneficial objectives.

Prospective impact of new farm policy paradigm on agricultural marketing infrastructure in Punjab

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The Punjab Mandi Board has been playing a significant role in revolutionizing the rural economy in many ways. Presently, it has established 154 regulated markets, 277 sub yards and 4006 purchasing centres in the state. The Board in collaboration with other departments has linked every single village with the metallic link roads. Consequently, the marketing of farm produce has become orderly and efficient, particularly at the assembling point. The manifold increase in agricultural production might not have been achieved without the successful development of an efficient marketing system. All these interventions pave the way for smooth procurement of food grains to maintain buffer stock and for public distribution system in which the share of Punjab to the central pool is 37.8 per cent in the case of wheat and 21.5 per cent in case of rice in the year of 2019-20 for which the state is considered to be the 'Food Bowl' of the country. Besides this, there is an unabridged lot of infrastructure developed by the Board in the state. The present study apart from highlighting the infrastructural development made by the Board throws light on the likely adverse effects of the dissolution of the APMC act wherein the farmers may be left at the mercy of private companies after the end of the regulated market system. Resultantly, the income of Board and state revenue would drastically decline which would adversely affect the funding of various developmental works, market infrastructure and road network systems in the state.

Economics of agro-processing industries in Jammu & Kashmir

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The Union Territory of Jammu and Kashmir, has already created a niche for its horticultural products. The diversity in agro-climatic conditions naturally provides ground for the cultivation of horticultural and other high-valued food and non-food products. However, poor infrastructural capacity, inadequate investment and poor marketing linkage pull down the growth of these high-valued crops. The real potential of these high-valued crops is still un-exploited and under-utilized. This paper maps agro-processing units in the state and assesses their efficiency, inclusiveness and prospects for future growth. Cobb-Douglas method is used to estimate the marginal productivity of labour and capital whereas other statistical methods are used to quantify the related data from the agro-processing industries. The findings show that the agro-processing sector is dominated by small-scale industries and is labour-intensive, and lacks capital investment and market linkages. The need is to bring investment, upskill the labour-force as well as improve the marketing infrastructure in the region to provide the required incentives to push the sector to achieve its full potential.

Growth rate and instability of groundnut production in Odisha: A statistical modelling approach

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The oilseeds play a major role in increasing farmers' incomes mainly due to their greater economic value. In Odisha, groundnut, mustard, sunflower, sesame and castor are important oilseed crops. Groundnut shares 34% of the total area and 64% of the total production of oilseeds. This study explores the best fit model for area, yield and production of groundnut in Odisha to estimate the growth rate for the period 1970-71 to 2019-20 and further divided into pre-liberalisation (1970-71 to 1995-96) and post-liberalisation (1996-97 to 2019-20) periods. The models considered in the analysis are linear, logarithmic model, quadratic, compound and power model. Durbin-Watson test, Shapiro-Wilk's test and park's test have been used for testing error assumptions. Based on the significance of parametric coefficient, residual diagnostics and the model fit statistics, the best fit model has been selected for estimation of the growth rate. The growth in area and production of groundnut has decelerated in the post-liberalisation period, while yield growth has accelerated.

Urbanisation and farming systems in the semi-arid regions: A case study of Hyderabad, India

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Urbanisation induced agricultural land-use change is an important policy concern to ensure food and nutritional security and sustainability of farming systems. Urbanisation related pressures and opportunities influence farm households' decisions on the allocation of resources and produce diverse farming systems. Utilising farmer FGDs from six villages around Hyderabad, and qualitative empirical analysis, the present study identifies five dominant farming systems. Intensification of agricultural production and diversification into non-agricultural activities are the predominant system strategies at the urban-rural interface. This study benchmarks and provides a baseline to explore forces underlying farming system changes to develop urban-spatial and rural-development policies.

Intensity and adoption of coping strategies to climate change: Evidence from rural households in Maharashtra

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This study has evaluated climate change adaptation and mitigation strategies in the three vulnerable districts (Parbhani, Sindhudurg, and Ahmednagar) of Maharashtra employing the Double-Hurdle Model. Primary data from 180 households (60 from each district) were collected in 2020-21 to analyse 44 coping strategies identified. The highest intensity of adoption was in Ahmednagar (0.12), followed by Parbhani (0.10) and Sindhudurg (0.10). A majority of high-level adopters were from Sindhudurg (31), followed by Ahmednagar (29) and Parbhani (26). Education, family members engaged in farming, and access to credit in Parbhani; farm size, access to credit, and social participation in Sindhudurg; and, herd size has a positive significant influence on the probability of adoption in Ahmednagar. The family members engaged in farming and education level in Parbhani, age and drought frequency in Sindhudurg, and monthly gross income in Ahmednagar has a positive significant influence on the intensity of adoption.

Socio-economic analysis of agroforestry systems in eastern ghat highland zone of Odisha

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The present study is the outcome of a socio-economic diagnosis of traditional as well as commercial agroforestry practices followed by farmers in the Eastern Ghat High Land Zone of Odisha. Tree species like Mangifera indica, Anacardium occidentale, Tectona grandis, Eucalyptus spp., and Bamboo were dominant species in the traditional system whereas, Mangifera indica and Eucalyptus spp. were the main species of commercial agroforestry. Fruits and Fuelwood (60.2 %) was the major driving force for agroforestry adoption followed by additional income (25.2 %) and shade (18.8 %) in the traditional agroforestry region while additional income (74.8 %) was the major factor in the commercial agroforestry region. The net return from tree produce ha^{-1} per annum in the traditional system was Rs. 1513, 982 and 627 for marginal, small and medium farmers, respectively. In the commercial region, B:C ratio has been found higher (3.28) for Mango based agroforestry than Eucalyptus (2.93) and Bamboo (2.84) based bund system. Although traditional agroforestry seems less promising as compared to commercial agroforestry. Both forms of agroforestry have specific roles to play in the livelihoods and industrial development, which have to be carefully nurtured for their sustainability

Optimizing resource use efficiency of major farming systems: a study in the hills of Himachal Pradesh

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Using primary data on 240 farmers, this study examines the resource use efficiency of predominant farming systems in the hills of Himachal Pradesh and optimizes the existing resource use using linear programming technique. Six predominant farming systems were identified and dairy was an important component in each farming system. The study reveals the under-utilization of inputs under consideration for all farming systems. The optimization results indicate that there is a substantial scope of increasing farm income through optimal use of the existing resources. Also, an increase in the availability of binding resources can enhance the per farm net income of the farmers; indicating the need to provide more resources to the hill farmers for increasing their income and improving livelihood security.

The Indian oilseeds scenario: An economic perspective

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The oilseed sector occupies an important position in India's agricultural economy. India is the fifth largest oilseed producing country in the world (8%) after the USA (29%), Brazil (22%), Argentina (15%) and China (11%). The annual growth rate in area and production is positive and highest for castor, followed by soybean and sesame. The highest share in the area (42%) and production (39%) is of soybean. The increase in income level, as well as imports, has boosted the per capita consumption of edible oils in India. Palm oil accounts for 55% of the total edible oil imports. The export of de-oiled meals is found to be in a greater proportion than that of oilseeds and edible oils.

Wheat production in India: Adaptability to climate change and prospects

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Wheat is the major food crop produced and consumed in India. Wheat is mostly cultivated in northern plains. Over the years, climate change has, however, adversely affected the productivity of wheat. Considering these, an attempt has been made to assess the impact of climate change on wheat and to find a relationship between factors responsible for climate change and wheat production in India. Forecasting for 10 years has been made based on data of 25 years (1994-2018) employing the Box-Jenkin ARIMA model of the total production and total consumption of wheat. The ARIMA model of production selected for this study is of the order (1,1,0) and for consumption, it is of the order (0,1,2). The findings will help in suggesting whether India will be self-sufficient in total wheat production against the consistently increasing demand for wheat.

Sustainability of livestock agriculture in Punjab: Trade-off between lower emissions and higher productivity

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The study, based on primary data from 180 mixed farms with a herd size of 1064, was undertaken to take stock of the methane emission from dairying. The analysis focused on comparing the different diary species in terms of their methane emission concerning their milk yield, and it established the supremacy of crossbred cows as being the most environmentally friendly with the carbon footprint of 681.6 g CO_2-e/kg milk, concerning 836.1 g CO_2-e/kg milk for buffalo, and 900.9 g CO_2-e/kg milk for an indigenous cow. The study leaves a word of caution against advocating the switch to crossbred cattle as has been generally done in the past. Rather, the efforts may be directed towards the productivity enhancement of low methane-emitting indigenous cattle. The long-term solution for enhancing the sustainability of livestock production systems lies in lowering their contribution to methane emission.

Assessment of dissemination methods and constraints in the path of implementation of paddy straw management machinery in Punjab

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The study concerning the deliberate propagation methods and related constraints in the implementation of straw management machinery was conducted at Punjab Agricultural University (PAU), Ludhiana (2019-2020). The prime focus of the current research is to study the mode of propagation adopted by PAU and related constraints that are acting as a stumbling block to agricultural as well as environmental sustainability. For ascertaining the dissemination measures (which measure is efficient in implementation at the state level) and constraints in the adoption, the survey of 180 farmers was conducted which helps in analyzing which measure is effective in community mobilization towards straw management machinery adoption in addition to determining the major and minor constraint that hinders the level of implementation. Weighted mean scores and rank orders were calculated for the dissemination methods and constraints. The results reflect that the dissemination methods 'Organizing bi-annual Kisan mela for effective dissemination of the technology and arranging technology advancement extension activities for rural farmers' were the most effective in making farmers aware of straw management machinery with a weighted mean score of 2.63 and 2.49 respectively. The least effective was 'Online mode of dissemination during Covid19 pandemic' with a low weighted mean score of 2.11. For ascertaining constraints, the outcomes of this study showed that many factors can affect the decisions of farmers to accept and adopt the paddy residue management technology, but the cost is the most significant, followed by risks.

Production diversification, nutritional and dietary diversity of marginal and small farmers in Kanyakumari and Perambalur districts of Tamil Nadu

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This study assesses production diversification, nutritional status, and dietary diversity of marginal and small farming households in Kanyakumari and Perambalur. The study used a 7-day recall period to better understand the food habit heterogeneity, diet quality, and dietary diversity. There was a significant disparity among the districts in terms of food intake levels. Farmers in the Perambalur district have diversified their production more than farmers in the Kanyakumari district. The dietary pattern and calorie intake confirmed that the Kanyakumari district was better than the Perambalur district. Even though Kanyakumari district was not diversifying their cropping system, their nutritional security was stable, because of their excellent nutrition education and knowledge.

Changing policies and their sway on food security of India

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The present study has attempted to analyse the food grain production and storage system in light of present agricultural reforms. Findings of the study revealed that FCI has to depend on space available through Central and State Warehousing Corporation and private players. The owned and hired storage facility by FCI is underutilized to the tune of 87 and 73% respectively as these are inept for long-term storage. The new agri-laws together will give full legal control of procurement, supply and storage of food grains in the hands of private players. With time the dissolution of the APMC Act would mean the end of the state-regulated market system and states will lose their powers to regulate commodities and won't have any right to enforce stock hoarding limits which can lead to fluctuation in retail prices. Ironically, on one hand, farmers will be swindled by traders who buy at a lower price and then stockpiled stocks will jack up prices for the end-consumer. The recent recommendation of NITI Ayog to cutting down coverage of NFSA in rural areas from 75% of the population to 60% and from 50% to 40% in urban areas will further increase food vulnerability. If food subsidy is converted in cash transfer under NFSA then again private players will exploit the consumers by demanding a high price for the essential commodities. The study has cautioned fear of hunger and food insecurity which could be avoided if central and state governments invest massively in cold storage, warehouses and modernize the food supply chain model. It will logically create a competitive market and will reduce the wastage of agro-produce. It will ultimately help both farmers and consumers while bringing in price stability and endure governments commitment towards food security.

Food security for below poverty line (BPL) population in J&K: Public distribution system entitlement analysis

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Poverty and food security is global concern. People in poverty are experiencing acute hunger due to lower purchasing power. In Jammu and Kashmir, more than one million people are living under the poverty line, i.e, their monthly expenditure is as low as Rs. 1000 and Rs. 816 in urban and rural areas respectively. In this article, we analysed the status of the food security scenario among the below poverty line population in J&K by examining the ability of the erstwhile State to produce food grains locally and the PDS entitlement of foodgrains. As regards the broader picture, we found out that if NFSA entitlement criteria are followed then the local production of foodgrains is sufficient to meet the local food demand. However, there is evidence from both the primary research as well as the secondary sources data that the monthly entitlement provided through PDS under NFSA is not sufficient to meet the consumption requirement of PDS beneficiaries. Each person under the BPL category has to

bear additional Rs. 270 to complete the basket of minimum monthly foodgrains requirement besides the purchase of PDS foodgrains. It attributes that the insufficient PDS foodgrains entitlement has serious repercussions on the monthly income of the BPL population as they have to purchase additional foodgrains at higher prices from the market. Thus, creating a higher risk of acute food insecurity among the BPL population in J&K, which could have got more exaggerated during the COVID-19 pandemic as the supply management of essential goods including PDS across the whole country got disrupted.

Assessment of vulnerability to expected nutrient deficiency in BIMARU states

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This study assesses the vulnerability of the population towards nutrient inadequacy as a measure to eradicate malnutrition or hidden hunger. By examining nutrient deficiency, we observe that calorie intake is insufficient among rural households of BIMARU state, especially for marginal landholding households and disadvantaged caste groups. Higher numbers of households were reported vulnerable to deficiency than currently deficient. The findings indicate that the situation might worsen in the future, and thus policies must focus on vulnerable groups.

Public distribution system, consumption pattern and the need for a transition from food security to nutrition security in India – An analysis

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Public Distribution System (PDS) is a rationing measure. PDS plays a crucial role in food security by acting as a safety net by distributing essentials at a subsidised rate. Food security is a subject closely related to the well-being of the majority of the people. With time, over the last 60 years, the Government of India have adopted different welfare policies to minimise food insecurity. To strengthen the public distribution system, in 2013, the National Food Security Act (NFSA) has been implemented where the Act ensures food and nutritional security

for the most vulnerable communities through fair price shops. However, over the past couple of years, the idea of providing nutrition security is also gaining ground which is very important to consider in this context. The central objective of this paper is to analyse the PDS in India vis-a-vis the changing consumption pattern of beneficiaries and the need for a transition from the idea of food security to the idea of nutrition security. The paper is based on secondary data and literature made available from various secondary sources and the study is analytical.

Review on agritourism tourism policy of Maharashtra

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Agritourism is an alternative tourism form that provides first-hand experience of agricultural practices in farmers' fields, authentic cuisines tastes, live rural celebrations and forms of arts. It is not a new practice, but gaining importance because of its' role in the creation of alternative income to farmers, and employment to rural youth. Maharashtra is the pioneer in agritourism and it has given importance in Maharashtra Tourism Policy 2016 by incorporating agritourism as one of the major potential areas to help small farmers. Now, the Government of Maharashtra has come up with clear guidelines to boost agritourism through its Agri Tourism Policy 2020. This paper discusses the complete details of the growth of Agritourism from a pilot project to an exclusive state public policy and its benefits to farmers, rural youth and women engaged in agriculture.

Author index

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