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Preface

Agricultural and rural development is an integral component of the Government policy for inclusive economic growth and alleviation of rural poverty. A new policy initiative has been taken to double farmers' income and increase rural non-farm employment opportunities. This policy shift coupled with the initiative for financial inclusion is expected to change income and livelihood opportunities in rural areas. It is expected that improved livelihood opportunities shall bring a visible change in the rural landscape of the country. It will also contribute significantly to the Sustainable Development Goals (SDGs) of "No poverty, Zero hunger, Reduced inequalities, and Life on land." The contributions to income of rural workers and nutrition will also have significant impacts on other SDGs like health and gender equality and help protect them against climate vulnerability.

The growth of agriculture and rural non-farm sector has been quite impressive and the latter now contributes more than 40% to farmers' income. Livestock and fisheries sector have registered more than 7% annual growth during the recent period. It is likely that these trends will consolidate in future, contributing to transformation of rural landscape in terms of rural livelihoods, rural institutions, and social capital. In view these developments, the theme of "Future of Indian Agriculture: Opportunities and Challenges" was taken for discussion at 28th annual conference of the Association being organized at the University of Agricultural Sciences, G.K.V.K., Bengaluru, during 16-18 December 2020. The issues of livelihood and institutional diversity, innovative agribusiness models, responsiveness of rural development programs, technology delivery and uptake, improved nutrition, access to markets, etc. are proposed for deliberations at the conference. The Covid-19 pandemic and lockdown has added new dimension to the theme. Good growth performance of Indian agriculture and its role in absorption of migrant labour, and potential role in economic revival have generated discussion among the researchers.There has been an overwhelming response from the paper contributors to the conference. The Conference President has recommended 13 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 S Rajendra Prasad, Vice-Chancellor, University of Agricultural Sciences, Bengaluru for consenting to host the Conference at very short notice. The Association is also grateful to Dr Dhanapal, G N, Registrar for guiding the organizational activities, and to Dr Siddayya, Professor & PG Co-ordinator, MBA (ABM), Department of Agricultural Marketing, Cooperation and Business Management 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 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*. IFPRI and ICRISAT have sponsored their technical sessions in the Conference.

Dr T Haque, Conference President and Dr P K Joshi, President, AERA have taken keen interest in various activities and programs of the conference. Led by Dr P S Birthal, Chief Editor, *Agricultural Economics Research Review*, a team consisting of Dr P Parthasarthy Rao, Dr Seema Bathla, Dr Surabhi Mittal, Dr S K Srivastava, Dr Balaji S J, Dr Sendhil R and Dr P Venkatesh 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 Surabhi Mittal, and Dr P Kumar, chairman and members of the Editorial Board of AERR 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
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New Delhi 110 012

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Public financing of Indian agriculture and its returns: some panel evidence

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Abstract This paper compares the effectiveness of public investment and input subsidies in augmenting agricultural production. It uses an autoregressive distributed lag (ARDL) model on time-series data at the national level and panel data at the state level. The paper finds that subsidies have a positive and significant impact in augmenting agricultural production in the short run only, and public investment is more effective at the national and subnational level in the short and long run. The range of long-run elasticity is 0.03–0.368 and short-run elasticity is 0.030–0.205. Therefore, input subsidies should be rationalized and funds diverted to farm investment.

Keywords Investment, subsidies, production, Indian agriculture

JEL codes E22, H20, Q14

Since independence, the agricultural sector — driven by technological and institutional factors—has undergone several phases of growth. The agricultural gross domestic product (GDP) grew less than 2% per annum until the mid-1960s. The green revolution relied on modern methods of production and technology—high yield variety (HYV) seeds, fertilizers, mechanization, and irrigation. The government made tremendous efforts to help farmers make efficient use of these techniques of production (inputs), improve agricultural growth, and boost the agricultural sector, but farmers were not able to adopt these adequately. To solve the problem, the Foodgrains Prices Committee (1964) recommended that the Government of India institute an agricultural subsidies scheme, and the central, state, and local governments began subsidizing inputs (fertilizers, electricity, irrigation, etc). Input subsidies have been increasing continually since then (Figure 1). The curve has been concave after 2014, but the decline is not as per expectations, and it still remains high. The gap between the mounting input subsidies and public investment has widened since 2005. Public investment remained constant up to 2002, despite some fluctuations, and improved slightly afterwards. But, since 1994 the increase in public investment has been less than the subsidies, and the gap widened after 2005.

In the 2015 financial year, the subsidy on fertilizers, INR 71,076 crore, was the highest of all input subsidies (Gulati et al. 2018), the water subsidy through irrigation and power was INR 37,246 crore, but public investment in Indian agriculture was only INR 42,313 crore. Agricultural subsidies increased—eating into government resources and raising the revenue deficit—and led public sector agricultural investment to fall (Gulati and Sharma 1995; Gulati and Bathla 2001; Chand and Kumar 2004; Singh 2014; Akber 2020).But input subsidies do not raise agricultural productivity (Akber and Paltasingh 2019 a), and these are losing their share in revenue (Vyas 2001) and have become unproductive and financially unsustainable (Fan et al. 2008).

The agricultural farm acts of 2020 ignore the issue of public financing of Indian agriculture.To what extent do public financing patterns help Indian agriculture? How effective are subsidies compared to public

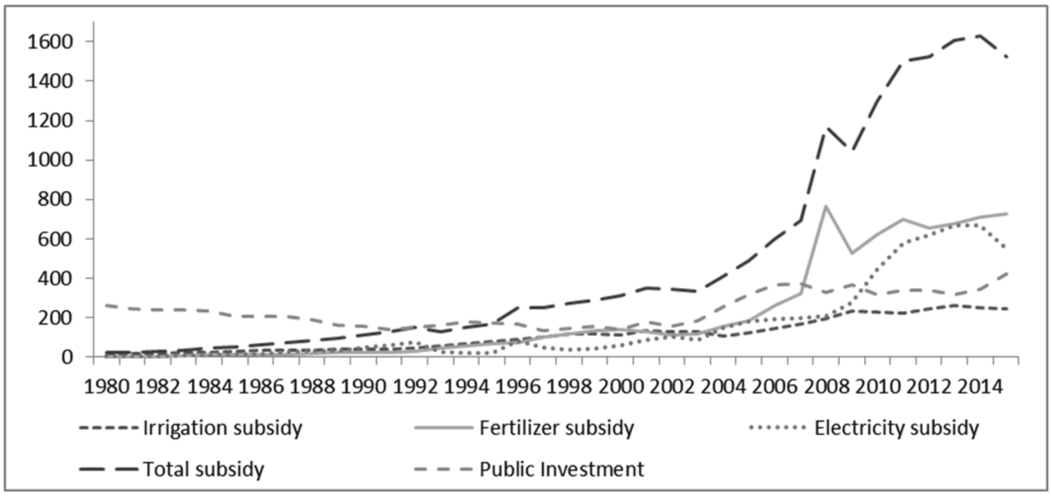

Figure 1 Input subsidies and investment in Indian agriculture in billion Rupees (2011-12 prices)
Source: Ministry of Agriculture, Government of India, CSO.

investment in improving agricultural production? This paper attempts an answer by analyzing the data at the national and subnational level using the auto-regressive distributive lag (ARDL) models. The results could have strong policy implications.

Materials and methods

Data and variables

This study is based on time series data for the 1980–2015 period (36 years) at the national level and on panel data for the 1990–2017 period (26 years) for 17 major agricultural states at the subnational level. The regression model incorporates public investment (gross capital formation in agriculture (GCFA) as per the Central Statistical Organisation (CSO), intensity of public canals, power consumption, and expenditure on agricultural research) and input subsidies, alongwith other explanatory variables (such as institutional credit, agricultural terms of trade, area under HYV seeds, cropping intensity, and weather index).

The data on the GCFA is compiled from various issues of the National Account Statistics (NAS). The data on canal intensity, power consumption, the area under HYV seeds, and cropping intensity is compiled from *Agricultural Statistics at Glance* pertaining to different years. The investment in research and education data is compiled from the Government of India. The agricultural terms of trade (gross barter terms of trade) are taken from the NAS of the CSO as the ratio of agricultural GDP deflator to non-agricultural GDP deflator.

The data on subsidies is compiled from the Ministry of Agriculture and Farmers' Welfare, Government of India; Gulati et al. (2018); and Indiastat.com. The wholesale price index (WPI) is used to deflate the data and to convert it into constant series (2011–12 prices). The credit data is compiled from the Reserve Bank of India (RBI); the weather data from the Ministry of Statistics and Programme Implementation, Government of India; and the state-wise data from the RBI. Table A1 in the Appendix lists the descriptive statistics and the definitions of all the variables.

Empirical model specification

Following Akber and Paltasingh (2019b) and Gulati and Bathla (2001), we develop two baseline models: the cumulative public investment as per CSO (Model 1) and the major components of public investment in terms of government canals and rural electrification (Model 2). Power consumption is used as a proxy for cumulative investment by public authority for rural electrification. Gulati and Bathla (2001) argue that the yearly supply of water and power is in fact the accumulation of years of public investment in the canals and power sector. The two baseline models are

$$lnPR_t = \alpha_0 + \alpha_1 lnI_{gt} + \alpha_2 lnSBSDY_t + \alpha_3 lnTOT_t + \alpha_4 lnCRDT_t + \alpha_5 lnHYV_t + \alpha_6\, lnWI_t + \alpha_7 lnPR_{t-1} + \varepsilon_{1t} \quad \ldots (1)$$

$lnPR_t = \alpha_0 + \alpha_1 lnCNL_t + \alpha_2 lnPC_t + \alpha_3 lnRE_t + \alpha_4 lnSBSDY_t + \alpha_5 lnTOT_t + \alpha_6\ lnCRDT_t + \alpha_7 lnCRI_t + \alpha_8 lnWI_t + \alpha_9 lnPR_{t-1} + \varepsilon_{1t}$ …(2)

where, '*ln*' represents natural logarithmic form, PR_t is agricultural production, I_{gt} is cumulative public investment,CNL_t is canal intensity (the ratio of net canal irrigated area to net sown area, as defined by the CSO within the Indian System of National Accounts (ISNA), PC_t represents power consumption, *RE* denotes the expenditure on agricultural research, *SBSDY* is input subsidy, TOT_t is terms of trade, $CRDT_t$ is credit, HYV_t is area under HYV seeds, and CRI_t is cropping intensity. WI_t is the weather index, defined—following Paltasingh et al. (2012) and Paltasingh and Goyari (2018)—as $WI = {R_t}/{1.07^{T_t}}$ where R_t is average seasonal rainfall and T is average temperature of the corresponding time period, and $\alpha's$ are the coefficients.

ARDL specification

To estimate the effectiveness of subsidies and investment in enhancing agricultural production, we use the ARDL bound test approach proposed by Pesaran et al. (2001). In the bound test approach, the long- and short-run estimates or elasticities can be estimated simultaneously and endogeneity is controlled for. The approach can be used whether the variables are stationary at 1(0) or 1(1) or if there is a mixture of stationarity of data. The error correction mechanism integrates the short-run elasticities with the long-run equilibrium without losing the information (Akber and Paltasingh 2020; Sehrawat and Giri 2018). For lag selection, we use the Akaike information criteria and Hanan-Quinn criteria. The approach involves estimating the unconditional error correction version (UECM) of the ARDL model:

$$y_t = \sum_{i=1}^{p} \emptyset_j\, y_{t-i} + \sum_{i=0}^{q} \vartheta_j\, x_{t-i} + \delta_1 y_{t-1} + \delta_2 x_{t-1} + \varepsilon_t$$

…(3)

where, y_{it} is the dependent variable (agricultural production), x_{it} is $(K \times 1)$ vector of explanatory variables (public investment, subsidies, TOT, credit, and so on), and δ_1 and δ_2 are the long-run parameters while $\emptyset_i$ and ϑ_i are the short-run parameters.

The residual term (ε_t) is assumed to be normally distributed. The null hypothesis of no cointegration among the variables in the equation is H_0: $\delta_1 = \delta_2 = 0$ against the alternative hypothesis H_1: $\delta_1 \neq \delta_2 \neq 0$ which implies the cointegration among variables.

If the calculated F-test statistic is more than the respective upper critical values, we reject H_0 of no cointegration and confirm the existence of a long-term relationship between the variables. If the calculated F-statistic is less than the respective lower bound critical values, we do not reject the H_0 and we conclude that there is no cointegration among variables. If the calculated F-statistic falls in-between the lower bound and the upper bound, the result is inconclusive.

The next step is to obtain the short-run dynamic parameters by estimating an error correction model with the long-run estimates. The short-run model can be estimated by

$$\Delta y_t = \beta_1 + \sum_{i=1}^{p} \emptyset_j\, \Delta y_{t-i} + \sum_{i=0}^{q} \vartheta_j\, \Delta x_{t-i} + \varphi ECM_{t-1} + \epsilon_t$$

…(4)

where $\emptyset_i$ and ϑ_i are the short-run dynamic parameters to equilibrium, and represent the short-run multiplier with respect to all the relevant variables. The error correction term ECM_{t-1} indicates the speed of adjustment back to the long-run equilibrium after a short-run shock.

Panel ARDL specification

To confirm the impact at the subnational level, we apply the panel ARDL model or the pooled mean group (PMG) estimator. The ARDL dynamic heterogeneous panel regression can be written by using the ARDL (p, q) approach where p is the lag of dependent variable and q is the lags of independent variables. The time period t = 1,2,3…,T, and groups i=1, 2, 3,..., N (Pesaran et al. 1999). The panel ARDL model can be written as:

$$y_{it} = \sum_{i=1}^{p} \emptyset_{ij} y_{i,t-j} + \sum_{i=0}^{q} \vartheta_{ij}\, x_{i,t-j} + \mu_i + \varepsilon_{it}$$

…(5)

where, y_{it} is the dependent variable (farm production), x_{it} is (vector of explanatory variables for group 'i', ϑ_{ji} are the $(K \times 1)$ coefficient vectors, $\emptyset_{ji}$ are the coefficients of the lagged dependent variable, μ_i are the unit-specific fixed effects, p and q are the optimal lag orders, and ε_{it} is the error term.

The short-run estimates can be written as:

$$\Delta y_{it} = \theta_i(y_{i,t-1} - \theta'_t x_{i,t}) + \sum_{j=1}^{p-1} \emptyset^*_{ij} y_{i,t-1} + \sum_{j=0}^{q-1} \vartheta^*_{ij} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it}$$

where

$\theta_i = -(1 - \sum_{j=1}^{p} \emptyset_{ij})$, $\emptyset_i = \sum_{j=0}^{q} \vartheta_{ij} / (1 - \sum_k \emptyset_{ik})$, $\emptyset^*_{ij} = -\sum_{m=j+1}^{p} \emptyset_{im}$; $j = 1, 2, \ldots P-1$,

and $\emptyset^*_{ij} = -\sum_{m=j+1}^{q} \vartheta_{im}$; $j = 1, 2, \ldots, q-1$.

Here, θ_i is the error-correcting speed of adjustment term for each unit. If $\theta_i = 0$, there is no evidence for a long-run relationship. The value of θ_i is expected to be highly significant and negative under the assumption that the variables show a return to long-run equilibrium.

Pesaran et al. (1997, 1999) propose the ‘pooled mean group’ (PMG) estimator, which combines both average and pooling the residuals. The given test incorporates the intercept, short-run coefficients, and different error variances across the groups. However, it holds the long-run coefficients to be equal across the groups like fixed effect estimators (Behera and Mishra 2019). The panel ARDL can be applied when the variables follow the integration of I(0), I(1), or when there is a mixture of both.

Results and discussion

Results of unit root test and optimal lag selection

We perform the unit root test with trend+intercept by the augmented Dickey–Fuller and Phillips–Perron tests. The results show that, except agricultural production, all the variables are non-stationary at level 1(0) (Table A2 in the Appendix). Therefore, we go for first difference 1(1) where all the variables have been found stationary. The mixture of stationarity of variables makes it appropriate to apply the ARDL to find the short- and long-run elasticities. Tables A3 and A4 in the Appendix present the result of optimal lag selection. The results of the Akaike information criteria (AIC), and Hannan–Quinn (HQ) information criteria, and Schwarz criteria (SC) indicate, respectively, two and one significant lags in the two model specifications respectively.

Long- and short-run elasticities at the national level

The results of the long-run elasticity of the ARDL model show that public sector investment in Indian agriculture positively and significantly impacts production (Table 1). The elasticity, 0.17, suggests that a 1% rise in public investment increases production by 0.17%; the coefficient is statistically significant at a 5% level of significance. Subsidies do not show any significant impact.

Farm production is significantly impacted by explanatory variables like institutional credit flow to agriculture, area under HYV seeds, etc. The elasticities—0.017 (institutional credit to agriculture) and 0.20 (area under HYV seeds)—are statistically significant at a 5% level of significance. The weather index negatively impacts farm production, but agricultural terms do not exert any significant effect.

Model 2 contains public investment as per broad series. The impact is positive and significant. The elasticity of government canal intensity, 0.37, implies that a 1% increase can induce a 0.37% rise in agricultural production; of power consumption, 0.19, implies a 0.19% rise; and of expenditure on agricultural R&D, 0.24, implies that a 1% increase can induce a 0.24% rise in agricultural production. The coefficients are statistically significant at 5% and 1% level of significance.

Subsidies do not show any significant impact in the longrun. This finding is in line with Chand and Kumar (2004), which finds that investment has a more significant impact on output than subsidies in the longrun. This finding is supported also by Akber and Paltasingh (2019 a), which finds that subsidies have no significant or positive impact on agricultural productivity.

In Model 2, agricultural production is positively and significantly impacted by credit, but not by cropping intensity, terms of trade, or the weather index. The values of the F-statistic are, respectively, 7.89 and 4.18 in both specifications—higher than the critical value of the lower bound and the upper bound at a 1% level of significance—confirm the existence of long-run cointegration in both the models.

Table 2 represents the result of short-run elasticities. In Model 1, the estimated short-run elasticity of lagged agricultural output is 0.12, but no significant impact is

Table 1 ARDL long"run elasticities of production for all–India level

Variable	Specification 1			Specification 2		
	Coefficient	Standard error	Probability	Coefficient	Standard error	Probability
Ln(IG)	0.166**	0.055	0.015			
Ln(CNL)				0.368**	0.169	0.041
Ln(PC)				0.187***	0.059	0.005
Ln(RE)				0.235**	0.016	0.047
Ln(SBSD)	0.115	0.074	0.153	–0.062	0.044	0.176
Ln(TOT)	0.43	0.403	0.625	–0.066	0.140	0.642
Ln(CRDT)	0.017**	0.094	0.010	0.066***	0.020	0.003
Ln(HYV)	0.200**	0.072	0.021			
Ln(CRI)				0.386	0.430	0.380
Ln(WI)	–0.141**	0.063	0.054	–0.002	0.017	0.912
Const.	–5.931	4.568	0.226	0.974***	0.388	0.021
Bounds test statistic	7.886			4.180		
Critical values for bounds test						
Level of significance		Lower bound 1(0)		Upper bound 1(1)		
10%		1.88		2.99		
5%		2.14		3.30		
1%		2.65		3.97		

Note: The asterisks (***), and (**) indicate significance at, respectively, 1% and 5% probability level.

Table 2 ARDL short–run elasticities of production for all–India level

Variable	Specification 1			Specification 2		
	Coefficient	Standard error	Probability	Coefficient	Standard error	Probability
ΔLnPR(1)	0.115	0.173	0.520	–0.137	0.168	0.423
ΔLn(IG)	0.062**	0.022	0.021			
ΔLn(CNL)				0.205**	0.082	0.021
ΔLn(PC)				0.163**	0.057	0.010
ΔLn(RE)				0.030*	0.017	0.082
ΔLn(SBSD)	0.133*	0.062	0.061	–0.054	0.036	0.155
ΔLn(TOT)	1.064***	0.274	0.002	–0.058	0.126	0.651
ΔLn(CRDT)	0.141**	0.048	0.023	0.057***	0.019	0.000
ΔLn(HYV)	0.074**	0.033	0.050			
ΔLn(CRI)			0.337	0.368	0.370	
ΔLn(WI)	0.076**	0.020	0.018	–0.002	0.015	0.912
ECM(–1)	–0.885***	0.173	0.000	–0.873***	0.218	0.000
Adjusted R-squared	0.92			0.93		
D–W Statistic	2.36			2.40		

Note: The asterisks ***, **, * indicate significance at 1%, 5%, and 10% probability level.

observed. With the coefficient of public investment, agricultural investment (public sector) has a positive and significant impact on output in the shortrun. The elasticity, 0.06, is statistically significant at a 1% probability level. Subsidies show a positive and significant impact, but the coefficient, 0.133, is weakly significant at a 10% level of significance. The terms of trade, institutional credit, area under HYV seeds, and the weather index have a positive and significant impact on agricultural output in the shortrun.

In Model 2, public investment exhibits a positive and significant impact on agricultural production; the elasticity is estimated at 0.205 for government canals, 0.163 for power consumption, and 0.030 for investment in agricultural R&D. Subsidies show a positive impact, 0.018, but the elasticity is not statistically significant. Farm production is positively and significantly impacted by institutional credit, but not by the terms of trade, cropping intensity, or the weather index.

The values of the lagged error correction mechanism are –0.885 and –0.873 and these are statistically highly significant at a 1% level of significance. The value of R-squared is, respectively, 0.92 and 0.93. We conclude that public investment is more effective in augmenting farm production than input subsidies in both the long and shortrun. Institutional credit and area under HYV seeds positively influence agricultural output in both the short and longrun.

We conduct several diagnostic tests—normality, serial correlation and heteroscedasticity, and the Ramsey reset test (Table A5 in the Appendix). The results show that this ARDL model passes all the diagnostic tests: there is no serial correlation, functional misspecification, or non-normal error. We use the CUSUM and cumulative CUSUM of the square test (CUSUMQ)to check the consistency in parameters.

Stability test

We perform the CUSUM and CSUSMQ tests to check the stability of the model. The estimated line is within the boundaries of critical lines at 5% significance; therefore, the model is stable (Figures A1–A4 in the Appendix).

Zone-wise and state-level analysis

Now, we compare the effectiveness of subsidies and investment in augmenting farm production at the subnational level. We consider 17 major states. We incorporate, along with public investment and subsidies, explanatory variables like agricultural terms of trade, institutional credit to agriculture, and cropping intensity. We calculate the public investment data by adding the capital expenditure on different variables like soil and water consumption, plantations, agricultural research and education, and so on.

We compile the data on subsidies from various issues of the RBI Handbook and annual reports of state electricity boards, and we calculate the subsidy data by adding the subsidy on irrigation, power, and fertilizer. We perform the Pesaran cross-section dependence test. The results confirm the existence of cross-section dependence across the states (Table A6 in the Appendix).

Unit root and lag selection tests

We use unit root tests—Levin–Lin–Chu and Im–Pesaran–Shin tests with intercept and intercept+trend to check the stationarity of the data set. The results confirm the presence of a mixture of stationarity of variables (Tables A7 and A8 in the Appendix). Some variables like production, subsidy, and terms of trade are stationary at level 1(0). The variables like public investment, institutional credit, and cropping intensity are stationary at first difference 1(1).

Next, we apply the panel ARDL model to find out the short- and long-run elasticities. Table A9 in the Appendix shows the result of the optimal lag selection. Two significant lags are indicated by the results of the Akaike information criterion (AIC), Schwarz information criterion (SC), and Hannan–Quinn information (HQ) criterion. Therefore, we use two lags in our model.

Panel cointegration

We use a cointegration test (Pedroni 2004) to check the existence of cointegration between the variables (Table A10 in the Appendix). The null hypothesis of no cointegration is rejected by five (of seven) tests—panel rho-statistic, panel PP-statistic, panel ADF-statistic, group PP statistic, and group ADFstatistic.

Long- and short-run elasticities at zone level

The results of the long-run elasticities of the panel ARDL model for various zones show that public

Table 3 Panel–ARDL long–run elasticities of production at zone level

Variable	Coefficient	Standard error	Probability
LnIG	0.130***	0.029	0.00
LnSBSD	0.026	0.085	0.75
LnTOT	–0.037	0.095	0.69
LnCRDT	–0.093**	0.040	0.02
LnCRI	2.061***	0.116	0.00

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5%, and 10% respectively.

investment has a positive and significant impact on agricultural production (Table 3). The elasticity is 0.130, suggesting that a 1% rise in public investment increases agricultural production at 0.130%. The coefficient is statistically significant at a 1% level of significance, but subsidies or the terms of trade do not show any significant impact. Institutional credit shows a negative impact (–0.093), and cropping intensity a positive impact. Public investment had a positive and significant impact in the north, south, and west zones and subsidies had a negative impact in the south and east zones (Table 4). Clearly, public investment positively and significantly impacts agricultural production in the longrun.

Tables 5 and 6 represent the results of the short-run estimates of the panel ARDL model at the state and zone level. The current level of agricultural production is negatively affected by the previous level of agricultural production. The elasticity of the lagged value of production is –0.375. The coefficient is significant at a 1% level of significance. The elasticity of public investment (0.015) and institutional credit (0.110) is positive, but only investment has a significant impact. Subsidies have a significant impact. Cropping intensity has a negative and significant impact (–0.634) at a 10% level of significance. The value of lagged error correction mechanization is –0.57 at a 5% level of significance.

Table 5 Panel–ARDL short–run elasticities of production at zone level

Variable	Coefficient	Standard error	Probability
Δ (PR(–1))	–0.375***	0.057	0.00
Δ (IG)	0.15*	0.08	0.07
Δ (SBSD)	0.47**	0.21	0.04
Δ (TOT)	–0.021	0.027	0.45
Δ (CRDT)	0.11	0.18	0.54
Δ (CRI)	–0.634*	0.34	0.06
ECM(–1)	–0.57**	0.109	0.03

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively

The short-run estimates at the zone level show that both public investment and subsidies enhance production in the short run, but the elasticity of subsidies is larger. In the short run, subsidies have a stronger effect than investment on agricultural production in nine major agricultural states, and public investment is effective in eight (Table 7). This finding supports the argument that subsidies are more effective than public investment in the shortrun. But subsidies have been found ineffective in the longrun, and public investment has a positive and significant impact in the short and longrun at the aggregate and state level. Therefore, public investment is effective than subsidies in the short and longrun, and there may be reason to

Table 4 Panel–ARDL long–run elasticities of production individual zones

Variable	North Zone			South Zone			East Zone			West Zone		
	Coeff.	Std. error	Prob.	Coeff.	Std. error	Prob.	Coeff.	Std. error	Prob.	Coeff.	Std. error	Prob.
LnIG	0.04***	0.01	0.00	0.15***	0.02	0.00	0.11	0.01	0.63	0.09**	0.03	0.01
LnSBSD	0.012	0.04	0.87	–0.21***	0.05	0.00	–0.07**	0.03	0.02	0.023	0.05	0.95
LnTOT	0.031	0.03	0.26	0.26***	0.08	0.00	0.021	0.03	0.90	0.014	0.08	0.95
LnCRDT	–0.051	0.09	0.58	0.03	0.03	0.45	0.13***	0.03	0.020	0.10***	0.03	0.00
Ln CRI	0.281**	0.14	0.04	1.95***	0.55	0.00	0.013	0.11	0.90	0.49**	0.21	0.03

Note: The asterisks (***), (**), and (*) indicate significance at 1%, 5%, and 10% respectively.

Table 6 Panel–ARDL short–run elasticities of production individual zones

Variable	North Zone			South Zone			East Zone			West Zone		
	Coeff.	Std. error	Prob.	Coeff.	Std. error	Prob.	Coeff.	Std. error	Prob.	Coeff.	Std. error	Prob.
ΔLn(PR(–1))	–0.34***	0.08	0.00	–0.15	0.21	0.46	–0.49***	0.1	0.00	–0.49***	0.1	0.00
ΔLn(IG)	0.11**	0.03	0.03	0.11*	0.06	0.07	0.021*	0.01	0.10	0.15***	0.01	0.00
ΔLn(SBSD)	0.13**	0.04	0.02	0.12*	0.03	0.06	0.09**	0.02	0.04	0.02	0.06	0.79
ΔLn(TOT)	–0.13	0.14	0.34	–0.03	0.02	0.15	0.06	0.02	0.89	0.11	0.02	0.89
ΔLn(CRDT)	0.36	0.27	0.18	0.09	0.61	0.88	0.13	0.16	0.43	0.13	0.16	0.43
ΔLn(CRI)	–0.38**	0.17	0.03	1.99	1.43	0.17	–0.67	0.49	0.17	–0.67	0.49	0.17
ECM(–1)	–0.33***	0.14	0.00	–0.66***	0.39	0.00	–0.49	0.19	0.00	–0.49***	0.19	0.00

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.

Table 7 Panel–ARDL short–run elasticities of production at individual states

Andhra Pradesh				Assam			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.348***	0.026	0.000	–Ln(PR)	–0.385***	0.018	0.000
ΔLn(IG)	–0.003	0.002	0.207	–Ln(IG)	0.028***	0.000	0.000
ΔLn(SBSD)	–0.078*	0.026	0.060	–Ln(SBSDY)	0.048***	0.002	0.000
ΔLn(TOT)	0.020**	0.003	0.010	–Ln(TOT)	1.009**	0.000	0.010
ΔLn(CRDT)	0.251**	0.085	0.050	–Ln(CRDT)	0.200***	0.004	0.000
ΔLn(CRI)	–4.919	3.682	0.273	–Ln(CRI)	0.000***	0.050	0.000
ECM(–1)	–0.551***	0.033	0.000	ECM(–1)	–0.008***	7.810	0.000
Bihar				Gujarat			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.618***	0.024	0.000	–Ln(PR)	–0.540***	0.030	0.000
ΔLn(IG)	–0.032***	0.000	0.000	–Ln(IG)	0.044***	0.003	0.000
ΔLn(SBSD)	–0.246***	0.012	0.000	–Ln(SBSD)	0.073**	0.016	0.010
ΔLn(TOT)	–0.009***	0.000	0.000	–Ln(TOT)	–0.001	0.004	0.838
ΔLn(CRDT)	0.158	0.282	0.180	–Ln(CRDT)	0.064	0.032	0.139
ΔLn(CRI)	–1.014**	0.092	0.030	–Ln(CRI)	0.023	–0.001	0.966
ECM(–1)	–0.143***	0.012	0.000	ECM(–1)	–0.022***	0.504	0.000
Haryana				Himachal Pradesh			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.231***	0.032	0.000	–Ln(PR)	–0.591***	0.028	0.000
ΔLn(IG)	0.003***	0.000	0.000	–Ln(IG)	–0.061***	0.001	0.000
ΔLn(SBSD)	–0.177***	0.008	0.000	–Ln(SBSD)	0.126***	0.017	0.000
ΔLn(TOT)	–0.028***	0.001	0.000	–Ln(TOT)	0.004***	0.000	0.000
ΔLn(CRDT)	0.021	0.053	0.716	–Ln(CRDT)	–0.128***	0.020	0.000
ΔLn(CRI)	–0.104***	0.021	0.010	–Ln(CRI)	0.002	0.057	0.980
ECM(–1)	–0.037***	0.003	0.000	ECM(–1)	–0.14***	0.000	0.000
Jammu & Kashmir				Karnataka			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.498***	0.041	0.000	–Ln(PR)	–0.326***	0.048	0.000
DLn(IG)	–0.015***	0.001	0.000	–Ln(IG)	0.028***	0.006	0.010
DLn(SBSD)	0.135***	0.012	0.000	–Ln(SBSD)	–0.246**	0.006	0.010

Contd...

DLn(TOT)	0.005***	0.000	0.000	–Ln(TOT)	–0.003	0.007	0.717
ΔLn(CRDT)	0.054**	0.011	0.010	–Ln(CRDT)	0.681	0.343	0.141
ΔLn(CRI)	–0.483	2.316	0.840	–Ln(CRI)	0.454	1.324	0.754
ECM(–1)	0.005***	0.000	0.000	ECM(–1)	–0.134**	0.034	0.020

	Kerala				Madhya Pradesh		
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.429***	0.024	0.000	–Ln(PR)	–0.337***	0.045	0.000
ΔLn(IG)	0.094***	0.003	0.000	–Ln(IG)	–0.016***	0.001	0.000
ΔLn(SBSD)	0.223***	0.018	0.000	–Ln(SBSD)	0.043***	0.006	0.000
ΔLn(TOT)	0.020***	0.002	0.000	–Ln(TOT)	0.042***	0.002	0.000
ΔLn(CRDT)	–0.847***	0.136	0.000	–Ln(CRDT)	0.196*	0.042	0.070
ΔLn(CRI)	0.336	0.323	0.370	–Ln(CRI)	–0.644**	0.234	0.010
ECM(–1)	–0.024***	0.001	0.000	ECM(–1)	–0.070**	0.016	0.020

	Maharashtra				Odisha		
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.221***	0.020	0.000	–Ln(PR)	–0.508***	0.034	0.000
ΔLn(IG)	0.119***	0.004	0.000	–Ln(IG)	–0.019***	0.012	0.000
ΔLn(SBSD)	–0.695***	0.068	0.000	–Ln(SBSD)	–0.096	0.004	0.214
ΔLn(TOT)	–0.117*	0.041	0.060	–Ln(TOT)	0.008**	0.003	0.057
ΔLn(CRDT)	1.888***	0.224	0.000	–Ln(CRDT)	–0.165	0.135	0.309
ΔLn(CRI)	–1.358**	0.458	0.050	–Ln(CRI)	–0.040	0.212	0.862
ECM(–1)	–0.700***	0.030	0.000	ECM(–1)	–0.012***	0.001	0.000

	Punjab				Rajasthan		
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.323***	0.028	0.000	–Ln(PR)	–0.577***	0.015	0.000
ΔLn(IG)	0.039***	0.000	0.000	–Ln(IG)	0.027***	0.001	0.000
ΔLn(SBSD)	–0.011***	0.002	0.000	–Ln(SBSD)	0.105***	0.014	0.000
ΔLn(TOT)	0.025**	0.000	0.010	–Ln(TOT)	0.060***	0.003	0.000
ΔLn(CRDT)	0.066***	0.006	0.000	–Ln(CRDT)	–0.240***	0.023	0.000
ΔLn(CRI)	–0.005	0.082	0.952	–Ln(CRI)	1.164	0.816	0.249
ECM(–1)	–0.010***	0.001	0.000	ECM(–1)	–0.161***	0.009	0.000

	Tamil Nadu				Uttar Pradesh		
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	0.394***	0.045	0.000	–Ln(PR)	–0.341***	0.022	0.000
ΔLn(IG)	–0.045***	0.006	0.000	–Ln(IG)	0.115***	0.001	0.000
ΔLn(SBSD)	–0.112**	0.025	0.020	–Ln(SBSD)	0.041	0.037	0.343
ΔLn(TOT)	0.066*	0.039	0.090	–Ln(TOT)	–0.431***	0.068	0.000
ΔLn(CRDT)	–1.552**	0.487	0.040	–Ln(CRDT)	1.269**	0.403	0.050
ΔLn(CRI)	–2.344	0.968	0.194	–Ln(CRI)	–0.491	1.238	0.718
ECM(–1)	–0.790***	0.122	0.000	ECM(–1)	–0.201***	0.011	0.000

	West Bengal		
Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.501***	0.028	0.000
ΔLn(IG)	–0.002*	0.001	0.060
ΔLn(SBSD)	0.070***	0.010	0.000
ΔLn(TOT)	–0.005	0.007	0.565
ΔLn(CRDT)	–0.049**	0.013	0.030
ΔLn(CRI)	–1.462	1.245	0.325
ECM(–1)	–0.032***	0.0008	0.000

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.

divert resources from subsidies to investment in infrastructure and irrigation, institutional extension services and area under HYV seeds.

Conclusions

This study empirically examines the effectiveness of input subsidies and public investment in augmenting farm production in Indian agriculture. The exercise is undertaken at the national level (for the 1980–2015 period) and at the subnational level (1990–2015) for 17 major agricultural states. After checking the stationarity of the data, the study adopts the ARDL model.

The trend analysis shows that input subsidies have increased continually over the years while public sector agricultural investment has fallen. Agricultural production is found to be highly and significantly affected by public investment in the short and longrun, but subsidies have been found to be effective in the short-run only. The results of the panel ARDL model confirm the aggregate-level results: public investment is more effective than subsidies, in that it is a stimulating factor, in both the long and shortrun but, in the shortrun, subsidies have a little edge over public investment.

The decline in public investment poses a threat to the sustainable growth of Indian agriculture. The policy implications of this study are that the decline must be arrested immediately, the provision of input subsidies should be rationalized by weighing their welfare effects against their cost to the exchequer. If an input subsidy is found ineffective, the resources should be diverted to public investment. However, research is needed to establish whether subsidies should be abolished.

References

Akber, N, and K R Paltasingh. 2019a. Investment, subsidy, and productivity in Indian agriculture: an empirical analysis. *Agricultural Economics Research Review,* 32(conference number):13–25. http://dx.doi.org/10.5958/0974–0279.2019.00014.4

Akber, N, and K R Paltasingh. 2019b. Is public investment complementary to private investment in Indian agriculture? evidence from NARDL application. *Agricultural Economics*, 50(5): 643–655. DOI: 10.1111/agec.12515.

Akber, N. 2020. Does input subsidy discourage public investment in Indian agriculture? evidence from ARDL applications. *Journal of Public Affairs*, e 2337. https://doi.org/10.1002/pa.2337

Akber, N, and K R Paltasingh. 2020. Market arrival of apples under risk in Jammu & Kashmir, India: evidence from an ARDL application. *Journal of Agribusiness in Developing and Emerging Economies*, 10(2):177–189. https://doi.org/10.1108/JADEE-03–2019–0033.

Behera, J, and A K Mishra, 2020. Renewable and non-renewable energy consumption and economic growth in G7 countries: evidence from panel autoregressive distributed lag P-ARDL model. *International Economics and Economic Policy,* 17(1):241–258. https://doi.org/10.1007/s10368–019–00446–1

Chand, R, and Kumar, P. 2004. Determinants of capital formation and agriculture growth: some new explorations. *Economic & Political Weekly,* 39(52):5611–5616. https://www.jstor.org/stable/4415977.

Dickey, D A, and Fuller, W A. 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74(366): 427–431. https://www.jstor.org/stable/2286348.

Dickey, D A, and Fuller, W A. 1981. Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica,* 49(4): 1057–1072. https://www.jstor.org/stable/1912517.

Fan, S, Gulati, A, and Thorat, S. 2008. Investment, subsidies, and pro poor growth in rural India. *Agricultural Economics,* 39(2): 163–170. https://doi/abs/10.1111/j.1574-0862.2008.00328.x

Foodgrain Prices Committee 1964, Report of the Foodgrain Prices Committee. New Delhi: Government of India.

Gulati, A, and Bathla, S. 2001. Capital formation in Indian agriculture: re-visiting the debate. *Economic & Political Weekly,* 36(20): 1697–1708. https://www.jstor.org/stable/4410633.

Gulati, A, and Sharma, A. 1995. Subsidy syndrome in Indian agriculture. *Economic &Political Weekly,* 30(39): A93-A102. https://www.jstor.org/stable/4403271.

Gulati, A, Terway, P, and Banerjee, P. 2018. Trends in Input Subsidies and Investments in Indian Agriculture, In: Ashok Gulati, M. Ferroni, and Yuan Zhou(Eds). *Supporting Indian Farms: The Smart Way*, Academic Foundation, New Delhi.

Im, K S, Pesaran, M H, and Shin, Y. 2003. Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115(1): 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7.

Jarque, C, and A Bera. 1987. A test for normality of observations and regression residuals. *International Statistical Review,* 55: 163–172. https://www.jstor.org/stable/1403192.

Levin, A, Lin, C F, and Chu, C S J. 2002. Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics*, 108(1): 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7.

National Account Statistics of Central Statistics Organization CSO – Various years. Back series 2011 and 2019.

Paltasingh, K R, and Goyari, P. 2018. Statistical modeling of crop weather relationship in India: a survey of evolutionary trend of methodologies. *Asian Journal of Agriculture and Development*, 15(1):41–60. https://ageconsearch.umn.edu/record/275688/.

Paltasingh, K R, Goyari, P, and Mishra, R K. 2012. Measuring weather impact on crop yield using aridity index: evidence from Odisha. *Agricultural Economics Research Review*, 25(2): 205–216. http://www.indianjournals.com/ijor.aspx?target=ijor:aerr&volume=25&issue=2&article=003.

Pedroni, P. 2004. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory* 20(3): 597–625. https://doi.org/10.1017/S0266466604203073.

Pesaran, MH, Y Shin, and R P Smith. 1997. Estimating long-run relationships in dynamic heterogeneous panels. DAE Working Papers Amalgamated Series-9721. https://doi.org/10.1016/0304-4076(94)01644-F.

Pesaran, M H, Y Shin, and R P Smith. 1999. Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, 94(446): 621–634. https://doi.org/10.2307/2670182.

Pesaran, M H, Y Shin, and R J Smith. 2001.Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics* 16(3): 289–326. https://DOI: 10.1002/jae.

Pesaran, M H. 2004. General diagnostic tests for cross-section dependence in panels. Unpublished manuscript, Faculty of Economics and Politics, University of Cambridge. https://link.springer.com/content/pdf/10.1007/s00181-020-01875-7.pdf.

Phillips, P C, and P Perron. 1988.Testing for a unit root in time series regression. *Biometrika, 75(*2): 335–346. https://doi.org/10.1093/biomet/75.2.335

Ramsey, J B. 1969. Tests for specification errors in classical linear least squares regression analysis. *Journal of the Royal Statistical Society: Series B Methodological*, *31*2, 350–371. https://www.jstor.org/stable/2984219.

Reserve Bank of India (RBI), 2007-19. Database on Indian Economy.

Sehrawat, M, and A K Giri. 2018. The impact of financial development, economic growth, income inequality on poverty: evidence from India. *Empirical Economics,* 55(4): 1585–1602.https://doi.org/10.1007/s00181–017–1321–7

Singh, P. 2014. Declining public investment in Indian agriculture after economic reforms: an interstate analysis. *Journal of Management & Public Policy,* 6(1): 21-33. http://www.indianjournals.com/ijor.aspx?target=ijor:jmpp1&volume=6&issue=1&article=003.

Vyas, V S. 2001. Agriculture: second round of economic reforms. *Economic & Political Weekly,* 36(10): 829–836. https://www.jstor.org/stable/4410372.

Appendix

Table A1 Descriptive statistics and definition of all variables

Variable	Definition	Mean	SD
Production (PR)	Total agricultural production (in million tonnes)	156.24	35.6
Investment(IG)	Public investment by government (in crore INR)	23,631	8,401
Canal intensity (CNI)	Ratio of area under government canals and net sown area	116.41	5.98
Electricity consumption (PC)	Power consumed for agriculture (in giga watt hour =106xkilowatt)	4,05,383	3,01,926
Research expenditure (RE)	Total expenditure incurred on agricultural research	16,439	14,286
Subsidy (SBSD)	Total subsidies provided (total of subsidies on irrigation, fertilizer, and electricity)	54,599	78,353
Terms of trade (TOT)	Gross barter terms of trade (ratio of agricultural GDP deflator to nonagricultural GDP deflator)	36.96	14.18
Credit (CRDT)	Institutional credit provided to farmers (in crore INR)	1,606	1,825
Area under HYV seeds (HYV)	Area under HYV seeds (in million ha)	61,475	10,509
Cropping intensity (CRI)	Ratio of net sown area to total cropped area (million ha)	132.55	5.292
Weather index (WI)	Weather index ($WI=R_t/1.07^T$)	95.263	86.75

Source: All the data are compiled from various sources like National Account Statistics, Govt. of India, Agricultural Statistics at Glance, Reserve Bank of India, and Indiastat.com, etc.

Table A2 Unit root test with trend and intercept

Variables	Augmented Dickey–Fuller (ADF)		Phillips–Perron (PP)	
	Level	1st difference	Level	1st difference
LnPR	–4.120**	—	–4.120**	—
LnIG	–2.512	–8.459***	–2.358	–8.459***
LnCNL	–2.404	–7.995***	–2.277	–9.174***
LnPC	–1.793	–6.421***	–1.765	–6.4081***
LnRE	–2.412	–7.917	–2.279	–10.9807
LnSBSD	–1.706	–4.007**	–1.852	–3.983**
Ln TOT	–1.263	–10.408	–1.761	–29.72
LnCRDT	–0.899	–5.381***	–0.978	–5.371***
LnHYV	–3.193	–4.998***	–2.529	–5.079***
LnCRI	–0.795	–10.109***	–0.991	–23.54***
LnWI	–2.972	–7.920***	–2.885	–8.656***

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5%, and 10% respectively.

Table A3 VAR lag selection criteria (for model specification1)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	88.535	NA	0.004	–4.796	–4.481	–4.689
1	91.589	4.669*	0.0043	–4.917	–4.557*	–4.794
2	92.853	1.858	0.0042*	–4.932*	–4.528	–4.794*

Note: The asterisk (*) indicates optimal lag as per the respective test.

Table A4 VAR lag selection criteria (for model specification 2)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	480.004	NA	0.0025	–27.647	–27.198	–27.494
1	762.780	382.579	0.0029	–38.398	–33.460	–36.714
2	957.402	148.828*	0.0031*	–43.964*	–34.537*	–40.749*

Note: The asterisk (*) indicates optimal lag as per the respective test.

Table A5 Diagnostic tests

Diagnostic Tests	Model specification 1		Model specification 2	
	F Stat.	P–value	F Stat.	P–value
Normality (Jarque–Bera) test	2.27	0.321	0.961	0.618
Serial correlation	0.39879	0.5349	2.079234	0.1388
Breusch–Pagan–Godfrey test	0.604942	0.8359	0.306431	0.973
ARCH test	0.450823	0.5074	0.378962	0.5431
Ramsey RESET test	2.982675	0.1156	0.1301	0.111

Source: Authors' estimation.

Table A6 Pesearn CD cross-section dependence test

Variable	Statistic	Probability
PR	12.406***	0.00
PB	10.396***	0.00
SBSD	53.055***	0.00
TOT	27.069***	0.00
CRDT	57.277***	0.00
CRI	18.208***	0.00

Note: The asterisks (***) indicate significance at 1% probability level.

Table A7 Unit root test with intercept

Variables	Levin–Lin–Chu		Im–Pesaran–Shin	
	Level	1st difference	Level	1st difference
LnPR	–2.46***	—–	–2.99***	—–
LnIG	1.55	9.30***	1.241	12.68***
LnSBSD	–10.98***	—–	–9.04***	—–
LnTOT	–8.58***	—–	7.77***	—–
LnCRDT	6.65	2.68***	11.31	–4.92***
Ln CRI	1.16	–7.70***	1.17	–10.2***

Note: The asterisks (***), (**) and (*) indicate significanceat 1%, 5% and 10% respectively.

Table A8 Unit root test with trend and intercept

Variables	Levin–Lin–Chu		Im–Pesaran–Shin	
	Level	1st difference	Level	1st difference
LnPR	–2.53***	–””	3.31***	–””
LnIG	–0.24	–6.36***	–0.64	10.61***
LnSBSD	–11.83***	–””	10.47***	–””
LnTOT	–9.480***	–””	–7.81***	–””
LnCRDT	6.656	–2.68***	11.31	–4.92***
LnCRI	2.047	–4.91***	0.385	–7.55

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.

Table A9VAR lag selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	27.26	NA	0.03	–0.44	–0.28	–0.37
1	110.71	154.72	0.00	–2.16	–1.97	–2.08
2	129.76	34.93*	0.00*	–2.53*	–2.32*	–2.45*

Note: The asterisk (*) indicates optimal lag as per the respective test

Table A10 Results of co–integration test (Pedroni 2004)

Various test	Statistics	Probabilities
Panel v statistic	–0.5855	0.7209
Panel rho statistic	–2.3249**	0.01
Panel PP statistic	–10.353***	0
Panel ADF statistic	–2.2886**	0.0111
Group rho statistic	–0.6247	0.2661
Group PP statistic	–12.23***	0
Group ADF statistic	–1.637**	0.0508

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.

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Income-induced effects of COVID-19 on the food consumption pattern of Indian households

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Abstract The lockdown, imposed nationwide to curb the spread of COVID-19, has disrupted economic activity and adversely affected the income of most households. The level and composition of household consumption is expected to change and create a disequilibrium in the economy through a downward shift in the demand curves of food and non-food items. The consumption pattern is likely to shift from non-essential to essential commodities. The consumption of high-value food commodities will decline comparatively higher than of staple foods. Interventions in the form of direct supplies of essential food items and cash doles will ensure the food security of the poor during the pandemic.

Keywords Consumption, income, expenditure elasticities, COVID-19

JEL codes I31, Q18, D19

Improving economic access to food has always been a priority on the agenda for sustaining food security in India. Household income, a major determinant of access to food, has witnessed consistent progress, and per capita income at the national level (at 2011–12 prices) has increased 5.64 times from INR 16,836 in 1965–66 to INR 94,954 in 2019–20. The level and composition of the food basket has undergone a significant shift over time (Srivastava et al. 2013). The available literature establishes a positive association between income level and food intake, though the marginal effect of income has been reducing over time, and it varies by economic class and geographical location (Radhakrishna and Ravi 1990; Kumar et al. 2011; Srivastava, Balaji, and Kolady 2016). Thus, a change (increase/decrease) in income has direct implications for food security.

The occurrence of the COVID-19 pandemic forced the Indian government to impose a 21-day nationwide lockdown on 24 March 2020 to curb the spread of the virus; the lockdown was extended later. The lockdown disrupted economic activity and adversely affected the income level of most households. This is evident from the 23.9% contraction in the gross domestic product (GDP) at constant (2011–12) prices in Q1 2020–21 (April to June) as compared to the 5.2% growth in Q1 2019–20 (Government of India 2020). The decline in income is expected to lead to a downward shift in the demand curves of food and non-food commodities and, therefore, a disequilibrium in the economy. An assessment of the income-induced change in consumption patterns is essential to understand consumer behaviour during the pandemic and draw implications on demand push measures to revive the economy.

In this context, the paper has examined consumption patterns and modelled consumer behaviour to simulate the likely effect of change in income on the level and composition of consumption expenditure under different scenarios in India. This paper examines the consumption pattern of Indian households; models consumer behaviour and estimates expenditure elasticities for the different food groups and non-food expenses; and constructs possible income scenarios for the year 2020–21 and simulates the likely effects of income shocks on consumption patterns.

Data and methodology

The study is based on the evidence from the nationally representative Consumer Expenditure Surveys (CES) of the National Sample Survey Office (NSSO). The consumption expenditure on food and non-food items is compared between the 50th (1993–94) and 68th rounds (2011–12) across sectors (rural and urban) and expenditure classes (based on decile values of monthly per capita consumption expenditure (MPCE)). For the temporal comparison of expenditure, values were expressed at constant (1987–88) prices using the consumer price index (CPI) for agricultural labour for the rural sector and the CPI for urban non-manual employees for the urban sector.

The consumption expenditure of a household is allocated among different food and non-food items in such a proportion to fulfil its demand. It is assumed that the household is a utility maximizer and it allocates its budget rationally. Therefore, for modelling consumer behaviour, it is essential to choose a model which satisfies the axiom of choice and which is consistent with the microeconomic theory of utility maximization. The Linear Approximation-Almost Ideal Demand System (LA-AIDS) model is widely used because it satisfies the axiom of choice exactly, and it is relatively easy to estimate and interpret, compatible with aggregation over consumers, and consistent with household budget data (Deaton and Meulbauer 1980; Alston and Chalfant 1993; Eales and Unnevehr 1994). This study uses the LA-AIDS to model consumer behaviour and estimate the expenditure elasticities of food and non-food items; it uses the latest available cross-sectional data of the CES pertaining to the year 2011–12 (68th round). The specification of the model is

$$S_i = a_i + \sum_{j=1}^{n} b_{ij} \ln p_{ij} + C_i \ln Y + d_i IMR + e_i \ln age$$
$$+ f_i \ln hhsize + g_i URBAN + e_i$$

where,

s_i = budget share of ith commodity in total expenditure, i = 1, 2, 3, …..n

lnp_{ij} = price of jth commodity group in ith equation in logarithmic form,

lnY = MPCE divided by the Stone price index in logarithmic form,

IMR_i= inverse mills ratio with respect to ith commodity,

age_i = age of household head in logarithmic form,

hhsize = household size in logarithmic form

URBAN = dummy for urban sector

Several commodities have a consumption value of zero for several households, due to variations in preference, infrequent purchasing, and/or misreporting (Keen 1986). To overcome the problem of zero observations, the two-step Heckman estimation procedure is used. First, a probit regression model is used to estimate the probability that a given household consumes a given commodity (Heien and Wessells 1990). This regression is used to estimate for each household the inverse Mills ratio (IMR), which is used as an instrument in the LA-AIDS model.

The prices used in the model are 'unit values', derived as the ratio of the expenditure and the quantity of commodities consumed by the household. As it is difficult to derive unit prices for non-food items, a price index for non-food commodities was constructed using the CPI (state-wise separately for rural and urban areas), the Stone price index for food commodities, and household-specific shares of food and non-food expenses in total consumption expenditure as weight. The Stone price index for food commodities is constructed using the formula

$$\ln I = \sum_i \varpi_i \ln p_i$$

where ϖ_i is the mean of the expenditure share of the ith commodity.

To be consistent with microeconomic theory (the consumer is a utility maximizer), certain restrictions were imposed: homogeneity of degree zero in prices and income (i.e., consumers have no money illusion); symmetrical cross elasticities; and additivity (all the budget shares add up to 1). Since the errors of this system of equations tend to be correlated as the samples drawn were almost identical, the seemingly unrelated regression estimation (SURE) model, proposed by Zellner (1962), was used to get efficient estimators of the model. The SURE model employs the feasible generalized least squares technique for estimation. The expenditure elasticity for i[th] commodity with respect to total food expenditure was estimated by the formula

$$n_i = 1 + \frac{C_i}{\varpi_i}$$

Using the estimated expenditure elasticities, the effect of income-induced change in total consumption expenditure on the level and composition of food and non-food consumption was simulated under three scenarios.

Scenario 1 assumes that the 26.68% decline in the private final consumption expenditure (PFCE) at 2011–12 prices in Q1 2020–21 over Q1 2019–20 will continue for all the subsequent three quarters (Q2, Q3, and Q4) in 2020–21. Thus, the overall decline in PFCE during the year 2020–21 would be 26.68% as compared to 2019–20.

Scenario 2 assumes a gradual recovery, wherein the change in the PFCE in Q2, Q3, and Q4 of 2020–21 would be –15%, –10%, and 0% over the respective quarters in 2019–20 and, in 2020–21, the PFCE will decline 12.54% (weighted average) overall.

Scenario 3 assumes 100% recovery from Q2 onwards, and the remaining quarters in 2020–21 will witness the same level of PFCE as in 2019–20; overall, the PFCE will decline 6.26%. The level and pattern of consumption expenditure during 2019–20, the baseline pre-COVID period, was obtained by inflating the values of 2011–12 CES with CPI.

Results and discussion

Consumption expenditure pattern of Indian households

According to the latest available 2011–12 CES, an average Indian household spends 44.27% of its total consumption expenditure on food and rest is spent on non-food expenses (Table 1).

Between 1993–94 and 2011–12, the average non-food expenditure (at constant prices) increased significantly, at 4.29% annual growth rate, as compared to only a marginal increase in food expenses. Consequently, the share of non-food expenses in total consumption expenditure increased from 37.8% in 1993–94 to 55.7% in 2011–12. A shift in the consumption pattern away from food is an expected phenomenon and is widely observed by several scholars (Kumar 1996; Meenakshi 1996; Rao 2000; Radhakrishna 2005). The consumption pattern varies significantly across rural and urban areas and by expenditure class. Although the absolute value of expenditure (on food and non-food) was relatively higher among urban households, rural households allocated a relatively higher proportion of their consumption expenditure to food in both years. Between 1993–94 and 2011–12, the

Table 1 Trends in consumption expenditure pattern of Indian households (1993–94 to 2011–12)

Year	Real expenditure (at 1987–88 prices)			Share in total expenditure (%)	
	Food	Non-food	Total	Food	Non-food
Rural					
1993–94	103	57	160	64.6	35.4
2011–12	107	113	221	48.6	51.4
CGR (%)	0.21	3.93	1.80	-15.9	15.9
Urban					
1993–94	153	112	265	57.64	42.36
2011–12	154	246	401	38.47	61.53
CGR (%)	0.05	4.47	2.33	-19.2	19.2
Total					
1993–94	116	71	187	62.2	37.8
2011–12	119	150	270	44.3	55.7
CGR (%)	0.16	4.29	2.07	-17.9	17.9

Source Authors' estimates

Table 2 Decile class wise consumption pattern in India in 2011–12 (%)

Items	Decile classes*										
	1	2	3	4	5	6	7	8	9	10	All
Total expenditure (INR/capita/month)	533	711	839	959	1,098	1,260	1,470	1,774	2,311	5,033	1,599
Non-Food	38.7	40.4	42.0	43.3	45.4	46.9	49.3	52.6	56.9	71.3	55.7
Food	61.3	59.6	58.0	56.7	54.6	53.1	50.7	47.4	43.1	28.7	44.3
Cereals	34.6	31.7	29.1	27.4	25.7	24.2	22.9	20.9	19.1	14.8	22.7
Pulses	8.0	7.5	7.5	7.3	6.9	6.8	6.7	6.4	6.0	4.9	6.4
Edible oils	9.3	9.1	8.7	8.4	8.1	8.0	7.8	7.3	6.8	5.5	7.4
Milk	8.1	11.5	14.0	15.9	18.1	19.5	20.2	22.3	23.4	22.2	19.2
Fruits	1.0	1.4	1.6	2.0	2.1	2.5	2.8	3.2	3.8	4.8	3.0
Vegetables	12.9	11.7	11.2	10.7	10.1	9.8	9.7	9.2	8.8	7.4	9.5
Non-veg	5.2	6.5	6.7	7.0	7.3	7.5	7.6	7.8	7.9	7.4	7.3
Other foods#	21.0	20.6	21.1	21.4	21.7	21.6	22.3	22.8	24.2	33.0	24.4

Source: Authors' estimates

*based on MPCE; # Other foods include dry fruits, beverages, snacks and processed items, cooked meals taken outside home, spices, sugar, and salt

percentage decline in the share of food in total consumption expenditure was relatively less among rural households. These evidences reveal a consistently higher propensity among rural households to consume food. Similarly, the consumption expenditure pattern across decile classes (based on the MPCE) revealed that although the absolute value of food and non-food expenditure increases as household income increases, the share of food in total consumption expenditure decreases (Table 2).

In 2011–12, the households in the bottom decile class allocated 61.3% of their total consumption expenditure to food as compared to only 28.7% by the households in the top decile class. The rising absolute values of expenditure across the successive expenditure classes, along with the relatively higher propensity of rural and poor households for consuming food, implies that raising income, particularly of these households, by providing attractive avenues of earning would have a positive and stronger impact on improving the overall food and nutritional security in the country.

The food basket of an average Indian household is dominated by cereals, followed by milk and milk products. In 2011–12 cereals constituted 22.7% of the total food expenditure and milk 19.2% (Table 2). Interestingly, the composition of the food basket varied by expenditure class: the share of cereals, pulses, edible oils, and vegetables in total food expenditure was higher among households in the lower expenditure classes, and the share of milk, fruits, non-vegetarian products, and other foods (including processed foods, dry fruits, beverages, etc.) was higher among households in the higher expenditure classes. This implies that as an Indian household's income increases, it diversifies its food basket and allocates a relatively higher proportion of its food budget to high-value food commodities such as milk, fruits, non-vegetarian products, etc. A similar relationship has been established in other studies (Carmelia et al. 2019). Conversely, in the situation of a decline in income, a household would tend towards consuming staple foods and making only necessary expenses. Such consumer behaviour has been simulated by estimating the expenditure elasticities of food items and non-food expenses.

Estimation of expenditure elasticities of food groups and non-food expenses

The coefficients of the LA-AIDS model applied on 2011–12 CES data are estimated (Table 3). The model includes the share equations for cereals, pulses, edible oils, milk, fruits, vegetables, non-vegetarian products, and non-food expenses. The coefficients for 'other

Table 3 Estimated parameters of LA-AIDS model using SURE estimation technique

Variables	Cereals	Pulses	Milk	Edible oils	Non-veg	Vegetables	Fruits	Non-food
Dependent variable: Proportion of respective item in total consumption expenditure								
Independent variables:								
Intercept	0.4692	0.0950	0.1902	0.1046	–0.0067	0.1521	0.0021	–0.0100
	(0.0021)	(0.0010)	(0.0036)	(0.0009)	(0.0022)	(0.0014)	(0.0008)	(0.0041)
Prices in logarithmic terms								
Cereals	0.0858	–0.0047	0.0085	–0.0060	–0.0017	–0.0147	–0.0034	0.0106
	(0.0004)	(0.0001)	(0.0002)	(0.0001)	(0.0003)	(0.0002)	(0.0001)	(0.0003)
Pulses	–0.0047	0.0204	–0.0042	–0.0045	0.0025	0.0027	–0.0024	0.0110
	(0.0001)	(0.0003)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)
Milk	0.0085	–0.0042^{NS}	–0.0008	–0.0018	0.0193	0.0070	–0.0009	–0.0058
	(0.0002)	(0.0001)	(0.0005)	(0.0001)	(0.0003)	(0.0002)	(0.0001)	(0.0004)
Edible oils	–0.0060	–0.0045	–0.0018	0.0341	0.0015	0.0023	–0.0005	0.0024
	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)
Non-veg products	–0.0017	0.0025	0.0193	0.0015	–0.0194	–0.0027	–0.0019	0.0019
	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0004)	(0.0002)	(0.0001)	(0.0003)
Vegetables	–0.0147	0.0027	0.0070	0.0023	–0.0027	0.0124	0.0009	0.0099
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0001)	(0.0002)
Fruits	–0.0034	–0.0024	–0.0009	–0.0005	–0.0019	0.0009	0.0039	0.0016
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Other foods	0.0038	–0.0056	–0.0110	–0.0055	0.0028	0.0047	–0.0010	–0.0341
	(0.0003)	(0.0001)	(0.0004)	(0.0001)	(0.0003)	(0.0002)	(0.0001)	(0.0005)
Non-food price index	0.0106	0.0110	–0.0058	0.0024	0.0019	0.0099	0.0016	–0.1102
	(0.0003)	(0.0002)	(0.0004)	(0.0002)	(0.0003)	(0.0002)	(0.0001)	(0.0007)
IMR	-	–0.0152	–0.0104	–0.0220	–0.0023	-	0.0036	-
	-	(0.0002)	(0.0005)	(0.0002)	(0.0003)	-	(0.0001)	-
MPCE_ln	–0.0783	0.0024	–0.0059	0.0007	0.0106	–0.0225	0.0008	0.1127
	(0.0003)	(0.0002)	(0.0008)	(0.0002)	(0.0005)	(0.0002)	(0.0001)	(0.0005)
Age_ln	0.0110	–0.0047	–0.0055	–0.0067	0.0018	0.0031	0.0004	–0.0117
	(0.0005)	(0.0001)	(0.0005)	(0.0001)	(0.0003)	(0.0003)	(0.0001)	(0.0010)
Household size_ln	–0.0008	0.0112	–0.1218	0.0139	0.0518	–0.0126	–0.0034	0.0136
	(0.0003)	(0.0006)	(0.0014)	(0.0005)	(0.0012)	(0.0002)	(0.0004)	(0.0006)
Urban dummy	–0.0288	–0.0004	–0.0018	0.0032	–0.0045	–0.0030	0.0017	0.0285
	(0.0003)	(0.0001)	(0.0005)	(0.0001)	(0.0003)	(0.0002)	(0.0001)	(0.0007)

Source Authors' estimates
NS: Non-significant. All other coefficients were found to be significant at 1% level of significance

foods' were estimated using additivity restriction imposed in the model. Many households reported zero consumption of pulses, milk, edible oils, fruits, and non-vegetarian products. For these commodities, IMRs were estimated and used in the LA-AIDS model as instruments to account for zero consumption bias. The effect of rural and urban areas on consumption pattern in the model was controlled using a dummy variable for urban areas.

The expenditure elasticities of food groups and non-food expenses are estimated (Table 4); these vary by commodity, implying a differential effect of income change on the consumption of different commodities. Among the food groups, cereals exhibited a positive expenditure elasticity value but, at 0.37, it was the lowest. Thus, with a change in income, cereal consumption will change, but only marginally. Edible oils, pulses, and vegetables are relatively more elastic,

Table 4 Likely change in income-induced (due to COVID-19) consumption expenditure during 2020–21

Particulars	Expenditure elasticity	Pre-COVID consumption expenditure (2019–20): INR/capita/month	Change in consumption expenditure during 2020–21**: (%)		
			Scenario 1	Scenario 2	Scenario 3
Cereals	0.37	238	–9.89	–4.65	–2.32
Pulses	0.53	67	–14.05	–6.60	–3.30
Milk	0.89	202	–23.62	–11.10	–5.54
Edible oils	0.42	78	–11.32	–5.32	–2.66
Non-veg	0.96	77	–25.56	–12.02	–6.00
Vegetables	0.58	100	–15.42	–7.25	–3.62
Fruits	1.25	32	–33.43	–15.71	–7.84
Other foods	1.29	256	–34.30	–16.12	–8.05
Food_total	0.80[#]	1,048	–21.24	–9.99	–4.98
Non-food	1.23	1,318	–32.79	–15.41	–7.69

Source Authors' estimates

**Scenario 1: With same decline in PFCE as during April-June; Scenario 2: With gradual recovery in remaining quarters; Scenario 3: With 100% recovery in remaining quarters

[#] Weighted average (using expenditure as weight) of elasticities of food groups

but in the case of a change in income, their consumption will change less than proportionately. For milk and non-vegetarian products, elasticity values are closer to 1. Fruits and other foods exhibited elastic expenditure elasticities, and a change in household income will change the consumption of these commodities more than proportionately. Overall, the average weighted (with expenditure share) elasticity of food is 0.80 (inelastic), implying that food is a necessary item for consumers. The expenditure elasticity of non-food expenses has been estimated at 1.23; thus, with a change in income, households will change their expenditure on non-food items more than proportionately. These results indicate that the impact of income change on consumption will vary by commodity and elasticity value.

The effect of the pandemic-led income shocks on consumption patterns

The COVID-19 pandemic has severely impacted food consumption: income has decreased; there has been a shift in the variety of food items to cereals; and meal patterns have changed (Tome et al. 2020). The impact was more pronounced due to supply shocks, as labour was not available during the lockdown for harvesting the crops, transport was stalled, and entry was restricted (FAO 2020 a, b, c). The pandemic is likely to have long-run implications on food systems—in the form of structural changes in the supply chain and in food consumption behaviour—but this study focuses mainly on the short-run implications.

The impact pathway (Figure 1) shows the short-run impact of the COVID-19 pandemic on the food consumption of Indian households. The impact was classified based on the uncertainty in income flows and on supply shocks. During the pandemic, income flow uncertainty was very high, ranging from deferred payment to total job loss. Most of the vulnerable people who depend on daily wages lost their jobs during the complete lockdown, and they were only partially reinstated once the lockdown was lifted, because businesses were crippled. While a part of the vulnerable households mitigated the situation by shifting their consumption basket towards cheaper food grains, a large part reduced their food consumption.

Supply shocks also affected food consumption because these restricted physical access to food and raised food prices steeply. Civil society organizations (CSO) and the central and state governments intervened in a major way and helped the vulnerable people to tide over this period through direct cash transfers, provision of food grains and free meals, etc. This study focuses only on the short-run impact on food consumption; it does not cover the extent of benefits through the interventions of governments and CSOs.

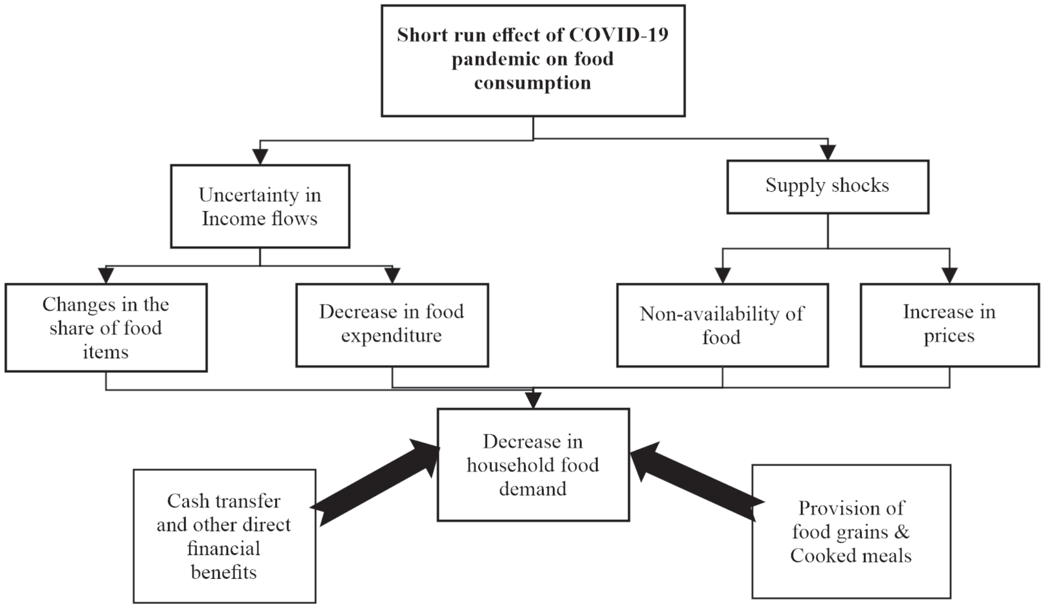

Figure 1 Pathways of likely impact of COVID-19 on food consumption

The average MPCE of INR 1,599 was allocated among various food and non-food items in the year 2011–12. Between 2011–12 and 2019–20, the general price level (CPI) in the country increased by 48% which inflated consumption expenditure to INR 2,366 for maintaining the same level (2011–12) of consumption in the year 2019–20. This was taken as the consumption expenditure in the baseline (pre-COVID) year 2019–20 and allocated to food and non-food items based on the 2011–12 consumption expenditure pattern (Table 4).

The nationwide lockdown disrupted all non-essential economic activity, and the gross value added (at 2011–12 prices) declined 22.8% during the first quarter Q1 (April-June) of 2020–21 as compared to Q1 2019–20 and, consequently, the PFCE declined 26.68%. The likely effect of the pandemic-led decline in income on consumption at the disaggregate level for the whole year 2020–21 is simulated under three scenarios using the estimated expenditure elasticities.

As discussed in the methodology section, overall consumption expenditure for the whole year 2020–21 is expected to decline 26.68% under Scenario 1, 12.54% under Scenario 2, and 6.36% under Scenario 3. As non-food items are relatively more elastic than food items, the decline in the expenditure on non-food items would be relatively steeper than on food. The decline in non-food expenditure is estimated to range between 7.69% and 32.79%, and food expenditure is expected to fall by 4.98% to 21.24% during 2020–21 under the three scenarios considered in this analysis (Table 4).

In absolute terms, per capita monthly non-food expenditure in 2020–21 will be INR 101–432 less than in 2019–20. The decline in absolute per capita monthly food expenditure is expected to range between INR 52 and INR 223. Within the food basket, cereals will witness the lowest decline in consumption (2.32%–9.89%). The decline in the consumption of high-value food commodities such as milk, non-vegetarian products, fruits, and other food products (beverages, dry fruits, processed foods, etc.) will be comparatively higher than staple foods (like cereals, pulses, and edible oils).

A decline in household income will differentially affect the level of consumption expenditure on different commodities, and the composition of the consumption basket is likely to change. Households will reallocate expenditure from non-essential to essential items. The share of non-food expenditure will decline, whereas essential items like food will gain in their share in total expenditure (Table 5). Within the food basket, the share of commodities that have inelastic demand will witness an increase in the food budget.

Table 5 Expected changes in consumption pattern due to COVID-19-led income shock (%)

Items	2019–20	2020–21		
		Scenario 1	Scenario 2	Scenario 3
Cereals	10.0	12.5	11.0	10.5
Pulses	2.8	3.4	3.1	2.9
Milk	8.5	9.0	8.7	8.6
Edible oils	3.3	4.0	3.6	3.4
Non-veg	3.2	3.3	3.3	3.3
Vegetables	4.2	4.9	4.5	4.3
Fruits	1.3	1.2	1.3	1.3
Other foods	10.8	9.8	10.4	10.6
Food_Total	44.3	48.2	45.8	45
Non-food	55.7	51.8	54.2	55.0
Overall	100	100	100	100

Source Authors' estimates
Note Scenario 1: With same decline in PFCE as during April-June
Scenario 2: With gradual recovery in remaining quarters
Scenario 3: With 100% recovery in remaining quarters

Implications of income-induced change in consumption pattern

The reduction in the level and change in the composition of consumption expenditure has definite implications on food and nutritional security and on the revival of the overall economy. In India, many people consume less than the recommended dietary allowance and remain undernourished (Srivastava et al. 2017). The income-induced decline in the level of food consumption is expected to aggravate the incidence of undernourishment in the country.

The reallocation of the food budget from relatively elastic commodities (such as fruits, other foods) to inelastic commodities will reduce the diet diversity and adversely affect the intake of nutrients like vitamins and minerals from these sources unless supplemented with non-food sources (medicines). Thus, the COVID-19-induced income shock is likely to make Indian households, particularly with low earning capacities, more vulnerable to food and nutritional insecurity. The central government has implemented a slew of measures to combat the difficulties faced by vulnerable people. The entitlement of food distributed through the public distribution system was doubled without any additional charges.

To help poor people and migrant workers, the central government instituted several schemes: cash transfers, deferment on interest payment, advancing payment of PM-Kisan scheme instalment, etc. The state governments also came up with several supportive and innovative measures, like cash transfers, in-kind transfer of essential commodities, and providing free meals through food counters. To ensure that food was available to the vulnerable sections of society and they had access to it, CSOs intervened timely in various ways (Press Information Bureau 2020); the effects of such interventions, not accounted in this study, are worth exploring in future research. A reduction in the demand for food and non-food items directly affects food and nutritional security and exerts a deflationary pressure in the economy that may, in turn, lead towards a recession. The strategy to revive economic growth must, therefore, include demand push measures.

Conclusions

Household income has a direct association with the level and composition of consumption expenditure. The evidence reveals that the consumption basket of Indian households is shifting gradually towards non-food expenses, though food still constitutes close to half the consumption expenditure. When income increases, an Indian household diversifies its food basket and allocates a relatively higher proportion of its food budget to high-value food commodities (such as milk, fruits, non-vegetarian products, and processed foods).

Conversely, a decline in income will reduce consumption expenditure, and a household would tend to restrict consumption to food staples and expenses to necessities. The COVID-19 pandemic has adversely affected the income of most households, and it is expected to create a disequilibrium in the economy by shifting the demand curves of food and non-food commodities downwards. This has definite implications for ensuring food and nutritional security and economic growth in the country. The estimated expenditure elasticities revealed that the income change will affect consumption differently by commodity and that it will lead to more than proportionate change in non-food expenses. Food expenses will exhibit inelastic demand and change less than proportionately due to change in income. The response within food commodities will also vary, depending on the elasticity values.

Due to the pandemic-led nationwide lockdown during the first quarter (Q1) of 2020–21, gross value-added declined 22.8% and the PFCE 26.68%. Depending on the trajectory of recovery during the remaining quarters, the decline in income may reduce non-food expenditure during 2020–21 by 7.69% to 32.79%, and food expenditure may fall 4.98% to 21.24%. The decline in the consumption of staple foods (cereals, pulses, and edible oils) will be lower than in high-value commodities (milk, non-vegetarian products, fruits, and other food products such as beverages and processed foods) Consequently, the consumption pattern is likely to shift from non-essential to essential items. The reduction in the level and change in the composition of consumption expenditure may aggravate the incidence of undernourishment and malnourishment and exert a deflationary pressure in the economy. The interventions of governments (central and state) and CSOs through various schemes, supplementary income, and welfare measures are expected to reduce the COVID-19-led income-induced impacts in the economy, and the overall strategy to revive the economy must include demand push measures.

References

Alston, J M, and J A Chalfant. 1993. The silence of the lambdas: a test of the almost ideal and Rotterdam models. *American Journal of Agricultural Economics* 75: 304–313.

Carmelia, A C, A B Frances, S Choudhury, F Harris, L Aleksandrowicz, J Milner, E J M Joy, S Agrawal, A D Dangour, and R Green. 2019. Future diets in India: a systematic review of food consumption projection studies. *Global Food Security* 23: 182–190

Deaton, A S, and J Muellbauer. 1980. An almost ideal demand system. *American Economic Review* 70: 359–68.

Eales, J S, and L J Unnevehr. 1988. Demand for beef and chicken products: separability and structural change. *American Journal of Agricultural Economics* 70(3): 521–532.

FAO. 2020a. COVID-19 pandemic–impact on food and agriculture: q&a. Food and Agriculture Organization of the United Nations. http://www.fao.org/2019-ncov/q-and-a/impact-on-food-and-agriculture/en

FAO. 2020b. The effect of COVID-19 on fisheries and aquaculture in Asia. Policy Brief. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/ca9545en/CA9545EN.pdf

FAO. 2020c. Impacts of coronavirus on food security and nutrition in Asia and the Pacific: building more resilient food systems. Policy Brief. Food and Agriculture Organization of the United Nations. http://www.fao.org/documents/card/en/c/ca9473en

Government of India. 2020. Press note on estimates of gross domestic product for the first quarter (April-June) 2020–21. National Statistical Office, Ministry of Statistics & Programme Implementation.http://www.mospi.gov.in/sites/default/files/press_release/PRESS_NOTE-Q1_2020–21.pdf

Heien, D, and R Wessells. 1990. Demand system estimation with microdata: a censored regression approach. *Journal of Business and Economic Statistics* 6: 313–325.

Keen, M. 1986. Zero expenditures and the estimation of Engel curves. *Journal of Applied Econometrics* 32: 560–568.

Kumar, P. 1996. Structural changes in consumption and small farm diversification. In *Small Farm Diversification: Problems and Prospects*, ed T Haque, National Centre for Agricultural Economics and Policy Research, New Delhi.

Kumar, P, A Kumar, P Shinoj, and S S Raju. 2011. Estimation of demand elasticity for food commodities in India. *Agricultural Economics Research Review* 24(1): 1–14.

Meenakshi, J V. 1996. How important are changes in taste: a state-level analysis of food demand. *Economic and Political Weekly* December 14: 3265–3269.

Press Information Bureau. 2020. Pradhan Mantri Garib Kalyan Package: Progress so far. http://pibarchive.nic.in/newsite/erelease.aspx?relid=202210.

Radhakrishna, R. 2005. Food and nutrition security of the poor. *Economic and Political Weekly* 60(18):1817–1,821.

Radhakrishna, R, and C Ravi. 1990. Food demand projections for India. Research report, Centre for Economics and Social Studies, Hyderabad.

Rao, C H H. 2000. Declining demand for foodgrains in rural India: causes and implications. *Economic and Political Weekly* January 22: 201–206.

Srivastava, S K, S J Balaji, and D Kolady. 2016. Is there a convergence in dietary energy intake among expenditure-classes in India? *Agricultural Economics Research Review* 29 (Conference number): 119–128.

Srivastava, S K, and R Chand. 2017. Tracking transitions in calorie-intake among Indian households: insights and Policy Implications. *Agricultural Economics Research Review* 30(1): 23–35.

Srivastava, S K, V C Mathur, N Sivaramane, R Kumar, R Hasan, and P C Meena. 2013. Unravelling food basket of Indian households: revisiting underlying changes and future food demand. *Indian Journal of Agricultural Economics* 68(4): 535–551.

Tome E, G Popovski, M Petkovic, B K Seljak, and D Kocev. 2020. COVID-19 pandemic changes the food consumption patterns. *Trends in Food Science & Technology* 104: 268–272.

Zellner, A. 1962. An efficient method of estimating seemingly unrelated regression equations and tests of aggregation bias. *Journal of the American Statistical Association* 57: 500–509.

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Interlinking dietary diversity, production diversity, and climate change: Non-separable farm household model approach

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Abstract The level of production diversity is an indirect measure of diet quality and nutritional security. But production decisions are impaired by changes in climate. This study provides an empirical application of the non-separable household model by linking the effect of exogenous variations in production decisions, via climate variability, on household dietary diversity. Climate-induced production shocks cause fluctuations in food supply and market prices and, thereby, decrease dietary diversity and nutritional security. To combat the effects of climate change on subsistence farm households and improve nutritional security, production diversity and farm income are equally important, and agricultural policy should aim to enhance both.

Keywords Production diversity, dietary diversity, non-separability, farm households, semi-arid tropics

JEL codes E23, E21, C33, Q121

In many empirical and theoretical studies of economic development, the farm household model plays a central role (Singh et al. 1986). The model integrates the production of goods consumed by a farm household into a standard utility maximization framework, and it has been used to provide important insights into a broad array of economic questions (Chayanov 1966). This model has been used in many research studies like nutrition and labour market linkages (Strauss 1982); labour supply, determination of wages, and shocks in agricultural productivity (Kaur 2019); risk and investment in human capital (Jacoby and Emanuel 1997); resource allocation among family members (Rangel and Duncan 2015); technology adoption (Barnum and Squire 1979; Conley and Udry 2010); microcredit and financial markets (Kaboski and Townsend 2011); and the interlinkage of climate change and production and consumption decisions (Dillon et al. 2015).

We elaborate on the background linkages of climatic factors, production activities, and consumption decisions in the conceptual framework (Figure 1), which focus the farm household as a central decision-making unit. We improve and formalize our original conceptual framework (Khed et al. 2018) and we make some adjustments to fit the context of this study. We define three possible pathways through which farmers' decisions can be influenced; two are related to climatic factors and one is independent of climatic factors. Changes in climate parameters can affect farmers directly or indirectly. The direct effects are on production activities such as crop and livestock, while indirect effects focus are food consumption. These influence the decision-making and well-being of farm households positively and negatively.

The independent effect refers to general socioeconomic characteristics such as age, education, and other household characteristics. The present study hypothesizes that production diversity positively influences household dietary diversity and, subsequently, household food security. However, farmers' production decisions potentially determined

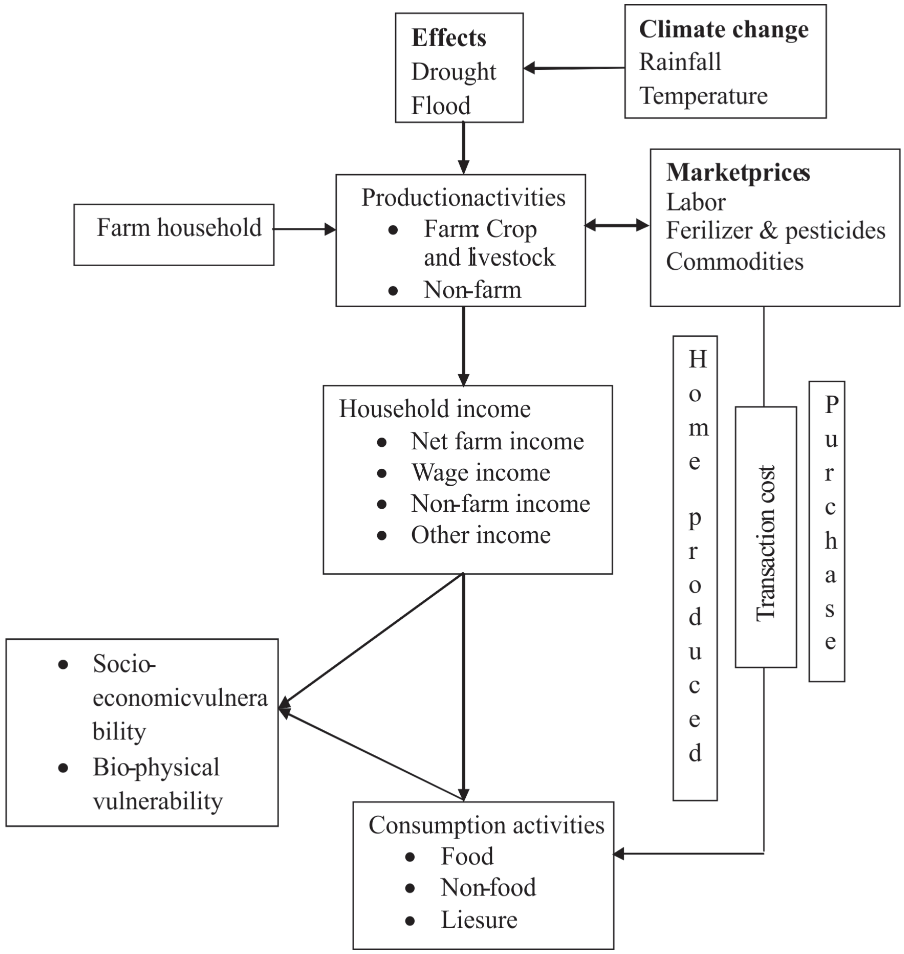

Figure 1 Conceptual framework of farm households

by climatic factors. Smallholder farmers, for instance, are more likely to grow food crops to ensure food self-sufficiency than grow cash crops and thus have low income elasticity in staple food expenses (Fafchamps 1992). Farm size is an important determinant of the quality of farm households' livelihoods—larger the farm, better the livelihood (Khed et al. 2018).

In India, the average farm size is 1.15 ha, and 85% of the farmers have landholdings of 2 hectares at most. They can produce diversified foods; therefore, they are almost self-reliant and less dependent on purchases. Farms may also be specializing in growing and selling commercial crops and, if necessary, buying most of its food needs (Nayak and Kumar 2019). The production decision is majorly determined by the distance between the farm and market (transaction cost). For a household at a remote location, the costs incurred in buying and selling goods and services, or transaction costs, are high, and the gap between selling and buying prices is large. This makes it follow the subsistence path. If transaction costs are low, then the household is more likely to specialize in the production of certain crops, ceteris paribus.

The agricultural production decisions and livelihood of farmers and other stakeholders are heavily influenced also by the increasing frequency of extreme climatic events such as droughts, floods, and heatwaves (Cheteni et al. 2020; Das and Ghosh 2019; Birthal et al. 2014), which reduce the farm-dependent consumers' choice of diversified food items. A general hypothesis derived from the multiple functions of farm households is that their production and consumption decisions are interrelated and influenced by climatic factors (Barnum and Squire 1979; Dillon et al. 2015; Singh et al. 1986). Here, we focus on the effect of exogenous variation in production decisions via climate variability on household dietary diversity.

To make this framework applicable to empirical analysis, we have to specify indicators to measure the effects of climate variability, agricultural production, and diet diversity. Some empirical studies find that production diversity remedies food insecurity (Dillon et al.;. 2015; Kumara et al. 2016; Sekabira and Shamim 2020) and others hold that markets constitute the solution (Sibhatu et al. 2015). The evidence is mixed and it may vary by region or country. Further, the limited studies observed the simultaneity of production and household consumption using climatic factors as an external variable. This study contributes to the literature by examining the link between agricultural production and dietary diversity using the data from India's semi-arid tropical regions on household consumption, agricultural production, and geospatial variables like rainfall and temperature.

Data and empirical strategy

The study is based primarily on secondary data collected from the 'Village Dynamics in South Asia (VDSA)' by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The project represents larger production regions within India's semi-arid tropics (SAT). We used the data for the 2009–14 period from 18 villages of 5 states: Andhra Pradesh (AP), Gujarat (GJ), Karnataka (KN), Maharashtra (MH), and Madhya Pradesh (MP)[1].

The data was collected continually from farm households. During data collection, the resident investigators re-interviewed the participating farm households several times per year to capture their dynamics—income, expenditure, consumption, investment, socio-demographic, farming practices, and climate variables. In each village every person in the sample households was interviewed at 15-day intervals using a standard questionnaire[2] (the detailed methodology is explained in Walker and Ryan (1990)). A sample of 30 cultivators and 10 landless labourer households under 3 different categories (small, medium, and large) was drawn in each village, and it formed the panel data for 664 farm households.

The average operational landholding of small farmers is 1.13 ha followed by medium (2.25 ha) and large (5.11 ha); the overall average across SAT villages is 2.53 ha. Households are separated further into degree day and rainfall deviation quartiles, where deviations from the historical mean of the climate variable are calculated to understand climate shocks. A positive shock indicates above-average degree days or rainfall while a negative shock indicates below-average.

Measurement of farm production diversity and dietary diversity

Farm production diversity is measured using two indices: the biodiversity index and the aggregated food production score. The biodiversity index is a simple count of all crops and livestock produced on the farm (Jones et al. 2014; Sibhatu et al. 2015; Kavitha et al. 2016). The aggregated food production score measures the sum of food groups produced on the farm. To construct the food production score, food crops were separated into 5 groups that correspond to 5 out of 12 groups that comprise the dietary diversity measure; non-food crops were excluded.

Dietary diversity is measured using two indices, similar to those used to measure production diversity, such as food item count, food group count. However, Jones et al. (2014) and Sibhatu et al. (2015) state that various approaches can be used to measure dietary diversity and emphasized to compare available quantities of particular foods, diets, and societal food behaviour. Therefore, many researchers use the food variety score—a simple count of food items consumed by households—and the dietary diversity score, an aggregated count of food groups consumed by the households (Cheteni et al. 2020; Sibhatu et al. 2015; Kumara et al. 2016).

Hence, the food variety score and dietary diversity score capture the access of households to different food products, their ability to afford these, and their food behaviour. The food groups are defined according to the guidelines of the Food and Agriculture Organization (FAO). The index ranges from 0 and 1, where 1 indicates positive effect on consumption of that particular item and 0 otherwise.

Non-separable farm household model

The non-separable farm household model is used to examine the connections between diversity of farm

[1] The study villages map is available at ICRISAT website (*http://vdsa.icrisat.ac.in/*).

[2] The questionnaire and data collection methods and the data are available at vdsa.icrisat.ac.in/VDSA-database.htm.

production, dietary diversity, and climate variability. The model explains the causal effect of diversity in production on dietary diversity. In the separable model, production and consumption are treated as two different sets. The definition of the interconnection between output (income) and consumption (nutrition) may be distorted by the inability to separate the causal path of the interlinkage, which correlates directly to production and consumption; that is, higher production (income) may have improved consumption (nutrition) and, similarly, households with better consumption (nutrition) may also have higher productivity and higher income.

By modeling this causal relationship using a non-separable household model and using exogenous variation in degree days, rainfall, and agricultural capital as an instrument, the causal direction of the production–dietary diversity relationship is more clearly identified (Dillon et al. 2015). Rainfall and degree day shocks are deviations from historical mean values (the historical mean and standard deviation of climate variables for the 1990–2014 period is given in Table A1 in the Appendix). A degree day is a cumulative measure of optimal temperatures for plant growth. A positive shock indicates above-average degree days or rainfall, while a negative shock indicates below-average. Hatfield et al. (2008) studied the impact of climate change on agriculture, land, water, and biodiversity using degree days as a climatic variable and found increase in temperature having a negative impact on crop yields and agricultural income.

Empirical model

In a non-separable household model, production and consumption decisions are jointly determined (Bardhan and Udry 1999; Strauss 1982). The detection of the direction of causality is probably confounded by a cross-sectional correlation. In this empirical strategy, a reduced form of regression equations of climate variables on diet would also be mis-specified due to omitted production variables (Dillon et al. 2015).

These challenges were addressed by developing a dynamic non-separable household model that used planting and harvest season data to improve the identification of production-consumption elasticity estimates. This strategy distinguishes between the timing of seasonal production decisions to understand the effect of planting period production decisions on post-harvest dietary diversity within a full agricultural year. We adopted the technique developed by Dillon et al. (2015) for panel data. In the formulation of the dynamic household model, households maximize expected utility given the production function (Y_t), time endowment (E^t), and intertemporal budget constraint (Q_t). The household's problem is to choose produced agricultural goods (x_{at}), agricultural inputs (V_t) and leisure (l_t) to maximize given utility (μ_t) and unobserved household characteristics (ε_t) such that:

$$U_t = \max E\left[\sum_{t=0}^{\infty} \beta^t\, u(x_{at}x_{mt}, l_t;\ \mu_t, \varepsilon_t)\right] \quad \ldots(1)$$

subject to the constraints:

$$Q_t = Q_t\,(L_t, V_t, A_t;\ \theta) \quad \ldots(2)$$

$$E^L = l_t + L^F_t + L^0_t \quad \ldots(3)$$

$$W_{t+1} = (1 + r_{t+1})\,[W_t + w_t\,(E^L - l_t) + \pi - p_{at}x_{at} - p_{mt}x_{mt}] \quad \ldots(4)$$

where $\pi_t = p_{at}Q_t\,(L_t, V_t, A_t;\ \theta) - w_tL_t - p_{vt}V_t - p_AA_t$ is the profit function over season t. The production function presented in Eq. (2) depends on the vectors of farm labour (L_t), variable inputs (V_t), fixed assets (A_t) such as land and capital, and seasonal climate variability (θ). The households time endowment (Eq. 3) is divided between leisure, on-farm (L^F_t) and off-farm labour (L^0_t). A standard dynamic household budget constraint is represented in Eq. (4).

In a separable household model, the demand for consumption of good c in period t is:

$$X_{ct} = x_{ct}\,(p_{mv}, p_{av}, w_v, r_{t+1}, \pi_t\,(p_{vV}, p_{aV}, p_V, p_{At};\ \theta), \gamma_V, \lambda_V;\ \mu_t, \varepsilon_t) \quad \ldots(5)$$

where good c consumption depends on market (p_{mv}) and agricultural prices (p_{av}), the price of variable inputs (p_v) such as agricultural labour, fertilizer, pesticides or herbicide, interest rates (r_{t+1}), farm profits (π_t) conditional on climate variability (θ), exogenous income (γ_V) and future prices via the marginal utility of wealth (λ_V).

Consumption also depends on observed (size and composition) and unobservable household characteristics (food preferences). Here, the problem can be disaggregated into a recursive two-period problem where household first maximize profits and then choose consumption levels if we assume separability (Bardhan and Udry 1999; Singh et al. 1986).

In non-separable formulation, production factors such as input prices influence the households consumption choices such that

$$X_{ct} = x_{ct}\,(p_{mv}, p_{av}, w_v, r_{t+1}, \pi_t\,(p_{vV}, p_{aV}, p_V, p_{At}; \theta), p_{vV}, p_{aV}, p_v p_A, \gamma_V, \lambda_V; \mu_t, \varepsilon_t) \quad \ldots(6)$$

Input prices affect household consumption when markets are imperfect. We cannot assume that only income affects household consumption demand. Therefore, the consumption demand equation includes not only variables that affect household income but also those that affect production decisions. The identification strategy to disentangle the joint production and consumption decision by the household is to model the production–climate variability relationship as a first-stage regression—controlling for other production variables, including labour availability and agricultural capital—while also controlling for prices and including household level fixed effects. The household fixed effects control for potentially omitted variables that are unobserved in our data set—including the interest rate and price expectations which, we assume, are similar across rural areas within states.

In the second stage, the relationship between production-related variables (agricultural revenue and production diversity) and dietary diversity was examined. The demand for a consumption good is generalizable to a dietary diversity indicator, or calories consumed by the food group after converting food quantities into calories—more precisely, the first-stage relationship between production (Y_{hvs}) is determined by input prices (p_v), the value of agricultural capital (p_A), climate variability (θ_{hs}) and household characteristics including household size and composition (X):

$$\ln Y_{hvs} = \beta^{pv} p_v + \beta^{A} p_A + \beta^{\theta}\theta_{hvs} + \beta^{\theta} X_{hvs} + \lambda_s + \varepsilon_{hvs} \quad \ldots(7)$$

where,

Y_{hvs} = agricultural return/production diversity

p_v = input prices in the village

p_a = value of agricultural capital

θ_{hs} = climate variability

λ_s = village fixed effects

ε_{hvs} = error term

Here, the relationship between production and climate variability includes the specification of Y_{hvs} as either crop group count score in the first set of regressions or agricultural revenue in the second set of regressions. Farm capital is a quasi-fixed stock over the agricultural season considered in the analysis. The motivation for the inclusion of agricultural capital is clear from the agricultural production function: agricultural capital and input prices directly affect the production and hence agricultural revenue. Household fixed effects (λ) are also included in this regression to control for agricultural market integration that may affect either access to inputs or marketing opportunities for farmers.

The second-stage equation establishes the relationship between production and dietary diversity at the household level, and it is given by:

$$\ln N_{hvs} = \beta^{Y} \ln Y_{hvs} + \beta^{pm} p_m + \beta^{pv} p_v + \beta^{X} X_{vhs} + \lambda s + \varepsilon_{hvs} \quad \ldots(8)$$

where N_{hvs} is dietary diversity for household 'h' in village 'v' in state 's'. Dietary diversity is determined by agricultural production Y, market price (p_m) during the post-harvest period, variable input prices (p_v), and household characteristics X including household composition which may affect household consumption. Here, Y is endogenously determined instruments with local climate variables and agricultural capital that are correlated with production variables but uncorrelated with dietary diversity. The plausibility of the excludability condition depends on the spatial intensity of climate shocks and market integration.

While climate shocks could have an effect on dietary diversity via price variation, the econometric specification includes market prices in the second stage. Further, the variability in the local climate causes a reduction in yield for local farmers, but these climate-induced yield reduction have less of an effect on equilibrium prices. Hence, a pathway through which climate variation affects dietary diversity is the number of crops available for the household's own consumption or, in our second specification, through the agricultural income generated from production, but price changes induced by the variability in the local climate do not affect dietary diversity.

Testing the exclusion restriction

The validity of the exclusion restriction potentially invalidates the identification of the effect of production variables on consumption outcomes. The primary concern is that climate variation may be correlated with dietary diversity. This would be the case if climate variation produced general equilibrium price changes that, in turn, affect consumption through market prices independently of their effect on production.

To test the mechanism and to find the evidence that the exclusion restriction is indeed invalid would be to estimate the effect of climate directly on market-level prices. We can directly estimate any potential general equilibrium effects of variations in the climate on market prices through a deviation from the historical average of either degree days or rainfall. To test a potential mechanism that would violate the exclusion restriction, we estimate the climate–price specification, the unit of analysis that most closely correlates to local markets. If strong correlations exist between climate shocks and market prices, the exclusion restriction would be violated.

Results and discussion

Farm household production decisions are determined by prices of inputs as well as by output and climate factors. To factor out the price from the climatic effect, it is imperative to examine the price of inputs and outputs during the study period. Hence, the average prices of agricultural inputs and composite prices for the food groups are computed and presented in Table 1.

Table 1 Input cost and output price (INR)

Inputs/Outputs	2009	2010	2011	2012	2013	2014	Average	CGAR
Inputs								
Agricultural wages for male	116.74	144.55	174.26	191.06	212.04	224.99	182.21	14.56***
	(47.90)	(52.14)	(77.54)	(62.05)	(64.28)	(64.28)	(72.08)	
Agricultural wages for female	70.20	99.33	119.33	123.93	140.07	143.03	119.35	15.55***
	(32.32)	(46.94)	(63.37)	(56.79)	(48.94)	(48.29)	(56.09)	
Fertilizer price/kg	8.33	13.25	15.89	15.47	17.58	18.95	15.33	11.26***
	(2.29)	(43.32)	(34.69)	(8.83)	(29.80)	(54.76)	(35.57)	
Pesticide price/kg	440.14	858.44	1288.73	97.00	1358.88	1747.09	1248.95	16.60***
	(553.29)	(1493.21)	(2979.68)	(25.76)	(2303.01)	(4115.26)	(2715.60)	
Outputs								
Market price of cereals/kg	17.49	16.98	18.45	22.28	23.69	25.17	20.90	7.83***
	(9.71)	(8.46)	(8.46)	(10.47)	(11.54)	(12.70)	(10.87)	
Market price of pulses/kg	37.55	81.64	46.75	53.41	51.44	58.15	56.81	9.14***
	(15.39)	(430.36)	(17.40)	(16.47)	(16.78)	(21.17)	(185.01)	
Market price of oilseeds/kg	30.38	38.07	72.22	72.28	47.67	50.11	53.10	12.07***
	(12.47)	(18.64)	(130.45)	(111.52)	(18.82)	(21.35)	(76.52)	
Market price of milk and milk	39.29	24.01	26.56	30.33	31.80	32.68	30.41	9.78***
products/litre	(61.75)	(16.14)	(6.94)	(24.32)	(6.75)	(7.65)	(26.25)	
Market price/egg	3.29	3.52	3.68	4.19	4.68	4.62	4.05	7.89***
	(1.20)	(0.73)	(0.73)	(0.64)	(0.72)	(0.63)	(0.93)	
Market price of meat/kg	150.15	166.40	191.15	225.63	245.96	256.42	209.39	14.66***
	(49.02)	(61.11)	(75.45)	(92.50)	(92.52)	(104.67)	(91.54)	
Market price of fish and	95.34	101.57	103.97	116.71	124.77	126.42	112.24	7.55***
seafood/kg	(38.46)	(35.32)	(36.69)	(46.96)	(43.75)	(40.08)	(42.00)	
Market price of sugar and	34.64	31.35	32.57	37.19	36.28	35.25	34.60	1.65**
sweets/kg	(4.78)	(5.00)	(4.07)	(4.58)	(5.12)	(5.85)	(5.38)	

Note: Figures in parentheses indicate the standard deviation *** and ** Significant at 1% and 5% level, respectively.

During the study period, the prices of all the inputs and food items were increased significantly. The average daily male agricultural wage rate was increased from INR 116 per day in 2009 to INR 224 per day in 2014 at a compound annual growth rate (CAGR) of 14.56%. Further, the wage rate of female labour was increased at a CAGR of 15.55%, and the current wage rate was around INR 143 per day. Similarly, the fertilizer prices were increased at a CAGR of 11.26% and pesticide prices were increased at a CAGR of 16.60%. Fertilizers are subsidized; therefore, their average price (INR 15.33 per kg) was cheaper than of pesticides (INR 1,248.95 per kg).

Food prices follow a predictable pattern. Farm households abound in villages; therefore, the supply of cereals and milk and milk products is abundant, and these are relatively cheap. Other high-value food items (fruits, vegetables, meat, and eggs) were more expensive. The CAGR of meat prices was highest (14.66%) and least for sugar and sweets (1.65%). Food prices are influenced by factors that affect the supply or demand of a product, with variations depending on the nature of the product.

Production, dietary diversity, and climatic shocks

This section examines the descriptive linkages between production, climate, and household dietary diversity. The sample farmers are categorized based on degree days and rainfall deviations quartiles, where the deviations from the historical mean of the climate variables are as explained in the methodology. The farmers in the first quartile experienced larger negative deviation (for example, below-average rainfall and fewer degree days) while those in the fourth experienced larger positive deviations (for example, higher rainfall and more degree days). An increase in the number of degree days negatively affect crop yield and agricultural return for a variety of crops (Dillon et al. 2015).

Agricultural production and climatic shocks

The descriptive statistics of agricultural production across the farms grouped under degree days and rainfall shock quartiles are given in Table 2. For both degree days and rainfall shock, an inverted-U-shape relationship was observed: the agricultural return was highest when the deviation from the average weather was small and smallest when the deviation was largely positive or negative. Negative rainfall shocks and positive degree day shocks have a positive effect on the agricultural return. Further, there was a strong relationship between degree day and rainfall variability and the variety of crops harvested by farmers that experienced above-mean temperature (degree days) and below- mean rainfall.

The relationship of crop groups with the number of food groups harvested by farmers also followed the inverted-U shape. However, the number of all crops harvested exhibits a weak positive relationship with degree day shocks and rainfall. This may be because many semi-arid crops are tolerant to drought and heat. Overall, the descriptive statistics expose the linkage between agricultural production and climatic shocks. The findings are in line with the results of Dillon et al. (2015), which examine the harvest value and production diversity across different quartiles of climate shocks.

Household dietary diversity and climatic shocks

The relationship between dietary diversity and food group consumption is explored in Table 3. The

Table 2 Production diversity and climate change

Production	Degree day shock quartile				Rainfall shock quartile				Overall
	– Shock		+ Shock		– Shock		+ Shock		
	1	2	1	2	1	2	1	2	
Total harvest value									
Harvest value (INR)	144,000	146,000	150,000	139,000	148,000	174,000	136,000	125,000	145,000
Number of crops and crop groups harvested by households									
Crop group harvested	2.70	2.78	2.88	2.73	2.66	2.89	2.79	2.76	2.78
Number of food group harvested	2.57	2.58	2.75	2.54	2.57	2.60	2.68	2.59	2.61
Number of crops harvested	4.27	4.25	4.48	4.22	4.39	3.91	4.39	4.10	4.22

Table 3 Dietary diversity and climate shocks

Dietary diversity	Degree day shock quartile				Rainfall shock quartile				Overall
	– Shock		+ Shock		– Shock		+ Shock		
	1	2	1	2	1	2	1	2	
Dietary diversity (Food group count)	8.59	8.45	8.62	8.78	8.40	8.87	8.61	8.60	8.62
Dietary diversity (Number of food items)	20.60	23.78	28.33	25.52	25.25	29.53	22.80	20.64	25.37
%age of food groups consumption from own production									
Cereals	36.40	44.13	44.28	41.23	49.87	33.34	39.19	43.03	41.22
Pulses	33.64	24.51	46.41	30.63	37.66	26.24	38.50	28.97	33.71
Oilseeds	0.48	0.92	0.69	1.00	1.62	0.11	0.79	0.53	0.76
Milk and milk products	50.66	60.44	44.97	42.88	56.38	42.69	49.17	49.21	49.75
Fruits	5.21	4.13	6.52	5.44	5.86	5.65	6.89	6.09	5.48
Vegetables	7.23	3.23	9.15	6.33	7.83	5.77	6.11	5.97	6.47
Eggs (Number)	2.92	3.03	2.12	2.89	2.06	3.32	1.96	2.68	2..82
Meat	2.72	3.16	1.69	4.62	1.09	3.21	2.06	2.43	6.54

estimates suggest that 'weather' variables are correlated with household dietary diversity.

The household dietary diversity of the 'number of food groups consumed' and degree days had a U-shaped response, implying that an increase in the temperature beyond the threshold negatively affects the number of food items consumed. The household dietary diversity of 'food items consumed' and degree days had an inverted-U-shaped response, implying that food group consumption is positively influenced.

Under rainfall shocks, however, the household dietary diversity of food groups and different food items consumed had an inverted-U-shaped relationship. That indicates that variations in climatic variables up to the threshold positively affect household dietary diversity; beyond the threshold, however, these variations negatively affect the household consumption of different food items or groups.

The percentage of food group consumption from own-farm production is presented in the second part of Table 3. Some drought- and heat-tolerant food groups show a positive relationship with climatic shocks; the remaining food groups show negative as well as mixed responses .

Relationship between dietary diversity, agricultural return, and operational landholding

The production and household dietary diversity estimates are presented in Table 4. The annual agricultural return ranged from INR 15,720 in the first

Table 4 Dietary diversity, agricultural return quartiles, and land class

	Agricultural return quartiles				Land class			Overall
	1	2	3	4	1	2	3	
Agricultural return (' '000)	15.72	51.10	109.69	402.96	71.38	121.20	271.10	144.87
PDD (Crop group count)	1.81	2.11	2.35	2.88	2.03	2.35	2.58	2.29
PD (Food crop group count)	1.75	2.07	2.26	2.66	1.56	2.04	2.37	2.18
Dietary diversity (Food group count)	8.08	8.07	8.27	8.49	8.26	8.22	8.21	8.23
Dietary diversity (Food item count)	20.74	21.33	23.02	24.30	22.44	22.11	22.10	22.25
Consumed 3 or fewer food groups (%)	0.00	0.70	0.00	0.52	0.35	0.50	1.14	0.60
Consumed 4 to 6 food groups (%)	0.00	0.70	0.00	0.00	0.35	0.00	0.57	0.30
Consumed 7 to 9 food groups (%)	98.94	98.59	98.10	96.91	98.95	97.52	96.02	97.74
Consumed 10 or more food groups (%)	1.06	0.00	1.90	2.58	0.35	1.98	2.27	1.36

quartile to INR 402,960 in the last (4th) quartile. The operational landholding size and agricultural return have a positive relationship. All crop groups and food crop groups had a positive relationship with agricultural return and landholding. It indicates that large operational landholdings helps to grow diversified crops and realize higher agricultural returns.

Household dietary diversity showed a positive relationship with agricultural returns. Curiously, the dietary diversity of small farmers was higher than of other landholding categories. This may be because sources other than agriculture provide small farmers a stable income and they consume primarily out of their production and also enjoy government benefits. More than 95% of farmers in all the climate quartiles and land classes.consumed 7-–9 food groups.

Relationship between agricultural returns and dietary diversity

In the first stage of the household panel regression (Table 5), we have seen the relationship between agricultural returns and farm household dietary

Table 5 Agricultural return and dietary diversity

Variables	Panel fixed effect model	IV: I stage	IV: II stage
Agricultural return			
Log of agricultural return	0.08***		1.03***
	(0.02)		(0.23)
Instrumental variables			
Deviation from mean degrees days		–0.01***	
		(0.004)	
Deviation from mean rainfall		0.06**	
		(0.03)	
Interaction of rainfall and degree days		–0.00006**	
		(0.06)	
Log value of agricultural capital		0.26***	
		(0.04)	
Local input prices			
Log male adult agricultural wage	–0.86***	–0.22*	–0.4***
	(0.12)	(0.12)	(0.1563)
Log fertilizer price	–0.08***	–0.08***	–0.04**
	(0.01)	(0.01)	(0.02)
Log food commodity price	–0.03	–0.08	–0.12*
	(0.05)	(0.06)	(0.06)
Household characteristics			
Age	0.03***	0.01	0.02***
	(0.01)	(0.01)	(0.01)
Education	0.08**	0.002	0.0142
	(0.04)	(0.03)	(0.036)
Family size	0.02	0.01	–0.06**
	(0.02)	(0.02)	(0.03)
Occupation	0.20***	0.09	–0.0526
	(0.08)	(0.07)	(0.0928)
Gender	0.30	0.32	–0.31
	(0.32)	(0.23)	(0.29)
Constant	0.71**	3.71***	–6.90***
	(0.33)	(0.56)	(1.52)
Durbin-Wu-Hausman χ^2		11.08**	
F-statistic	10.31***	13.2***	10.85***
Sargan and Basmann over-identification χ^2		4.6*	

Note: Figures in parentheses indicate the standard deviation

***, ** and * – Significant at 1%, 5%, and 10% level, respectively diversity. The first column of Table 5 shows the results of a panel regression fixed effect model, which is included for comparison, and which shows a positive and significant correlation between dietary diversity and agricultural return. Further, input costs—like wages for male agricultural workers and fertilizer costs—had a negative and significant ($P<0.01$) relation with dietary diversity. The synergistic effect of fertilizer costs and wages on food commodity prices negatively affect dietary diversity. The household characteristics—like age, education, and occupation—were also positively related to dietary diversity.

The second column shows the first-stage results in establishing the relationship between the instrumental variables (climate variability and quasi-fixed agricultural capital) and production. The results from the first-stage estimation suggest that a higher number of above-average degree days in a season, and lower-than-average rainfall, is associated with lower agricultural returns—as expected. The first-stage results also suggest that a higher number of above-average rainfall days is positively and significantly ($P<0.01$) associated with returns, whereas the degree days and interaction of rainfall and degree days are found to be negatively and significantly ($P<0.05$) associated with the returns. The first-stage results also provide some evidence that agricultural capital is relevant to explaining the production. The value of agricultural capital is positively associated with agricultural return and dietary diversity.

The third column shows the main results from the second stage of the instrumental variable panel data fixed effect model estimation. Agricultural returns have a positive and statistically significant impact ($P<0.01$) on dietary diversity. The set of instrumental variables was strongly correlated with the endogenous variable reflected by the F-statistics ($P<0.01$). The specification also passes two benchmark tests: the Durbin-Wu-Hausman test for endogeneity and the Sargan and Bassmann test for over-identification. The estimates suggest that a 1%-increase in agricultural return will increase dietary diversity by 1.03%.

The results also indicate that input prices have a negative and significant effect on household dietary diversity and the household head's age has a positive effect. Family size has a negative and significant impact: smaller the family size, greater the dietary diversity. Male-headed households are less likely than female-headed households to have a diversified diet.

Relationship between production diversity and dietary diversity

Table 6 presents the panel regression results of production diversity on dietary diversity. These have a positive and significant ($P<0.1$) relationship, as observed in the first stage of the household panel regression: a 1-unit increase in product diversity will increase dietary diversity by 0.03 units. Further, male agricultural labour wages and fertilizer prices have a negative and significant ($P<0.01$) relationship with production diversity. If commodity prices have a negative sign, a rise in the price would directly reduce consumption and, thereby, household dietary diversity.

The second column of Table 6 shows the first-stage results in establishing the relationship between the instrumental variables (climate variability and quasi-fixed agricultural capital) and production diversity. The results suggest that production diversity would decrease if the number of degree days in a season is higher than the average or if the rainfall is lower than the average. Higher-than-average rainfall is positively and significantly ($P<0.05$) associated with high production diversity. The instrumental variable—the value of agricultural capital—was positively associated with production diversity and dietary diversity. It shows that a 1%-increase in agricultural capital increases dietary diversity 0.26% through production diversity. Further, wages and output prices had a negative impact on diet diversification.

The third column of Table 6 shows the results from the second stage of the panel data fixed effects model with instrumental variable estimation. As expected, the production diversity had a positive and significant ($P<0.01$) impact on dietary diversity: an increase of 1 unit in production diversity increases dietary diversity by 1.76 units. The significant F-statistics indicates that the set of instrumental variables included in the model were strongly correlated with the endogenous variable. The specification also passes two benchmark tests: the Durbin-Wu-Hausman test for endogeneity and the Sargan and Bassmann test for over-identification. Family size, occupation, and the household head's gender—but not age—had a negative and statistically significant impact on household dietary diversity.

Table 6 Production diversity and dietary diversity

Variables	Panel fixed effect model	IV: I stage	IV: I stage
Production diversity	0.03*		1.76***
	(0.02)		(0.37)
Instrumental variables			
Deviation from mean degrees days		–0.01***	
		(0.004)	
Deviation from mean rainfall		0.06**	
		(0.03)	
Interaction of rainfall and degree days		–0.0001*	
		(0.05)	
Log value of agricultural capital		0.26***	
		(0.04)	
Local input prices			
Log male adult agricultural wage	–0.54***	–0.23*	–1.80***
	(0.11)	(0.12)	(0.22)
Log fertilizer price/kg	–0.08***	–0.08***	–0.01
	(0.01)	(0.01)	(0.02)
Log food commodity price/kg	–0.14***	–0.08*	–0.31***
	(0.06)	(0.06)	(0.06)
Household characteristics			
Age	0.01	0.01	0.03***
	(0.01)	(0.01)	(0.03)
Education	0.01	0.002	0.02
	(0.03)	(0.03)	(0.01)
Family size	0.01	0.01	–0.07**
	(0.02)	(0.02)	(0.02)
Occupation	0.09	0.09	–0.30**
	(0.08)	(0.07)	(0.06)
Gender	0.26	0.32	–0.54*
	(0.23)	(0.23)	(0.23)
Constant	5.59***	3.71***	–7.69***
	(0.54)	(0.56)	(1.69)
Durbin-Wu-Hausman χ^2		4.12*	
F Statistic	12.05***	11.4***	10.09***
Sargan and Basmann over-identification χ^2		15.43**	

Note: Figures in parenthesis indicates the standard deviation
***, ** and * – Significant at 1%, 5%, and 10% level, respectively

Smaller the family size, greater the dietary diversity. Households that practise agriculture as their primary occupation were less likely to have diversified diets than households that perform off-farm activities as a primary occupation. Agricultural income is not stable; farming households practised subsidiary occupation to make their income stable and improve dietary diversity. The dietary diversity was lower in male-headed households than in female-headed households. The results of the elasticity estimates of this study—production diversity and dietary diversity have a positive relationship—are supported by the findings of Dillon et al. (2015), for farming households in Nigeria, and of Sekabira and Shamim (2020), for farming households in Uganda.

Table 7 Market prices and climate shocks

Output prices	Cereals	Pulses	Oilseeds	Milk and milk products	Eggs	Meat	Fish and seafood	Sugar and sweets
Mean degree day deviation	0.03	1.45	0.51	0.47**	–0.77	–0.01	0.27	0.02
	(0.10)	(1.82)	(1.07)	(0.21)	(0.67)	(0.02)	(0.95)	(0.07)
Mean rainfall deviation	–0.26	–14.79	6.86	–0.70	–0.06	–0.21	–12.76*	–0.36
	(0.69)	(13.30)	(7.9125)	(1.54)	(5.26)	(0.12)	(7.60)	(0.53)
Interaction of rainfall and degree day deviation	–0.08	–6.07*	0.56	–1.10***	–0.37	0.06*	3.88*	–0.21
	(0.19)	(3.60)	(2.22)	(0.42)	(1.55)	(0.03)	(2.18)	(0.15)
Wage rates	0.02***	0.28*	0.28	–0.002	0.18***	–0.01	–0.33***	0.01**
	(0.01)	(0.15)	(0.09)	(0.02)	(0.05)	(0.001)	(0.08)	(0.01)
Fertilizer price	0.001**	–0.002	0.002	0.003***	0.01***	–0.000004***	0.02***	0.0001
	(0.001)	(0.009)	(0.01)	(0.001)	(0.003)	(0.00007)	(0.004)	(0.0004)
Constant	15.87***	5.05***	0.58***	27.42***	167.64***	5.32***	155.85***	31.97***
	(1.45)	(27.67)	(17.32)	(3.26)	(10.38)	(0.23)	(14.61)	(1.12)
Observation	108	108	108	108	108	108	108	108
R-square	0.61	0.68	0.66	0.71	0.52	0.55	0.54	0.56

Note: Figures in parentheses indicates the standard deviation
***, ** and * – Significant at 1%, 5%, and 10% level, respectively

Testing the exclusion restriction

If variations in climate parameters impact household dietary diversity through climate-induced price fluctuations, the instrument exclusion restriction is violated, and the instrumental variable results would be biased (Dillon et al. 2015). Therefore, we test the direct relationship between deviations in climate variables and local food commodity prices and present the results in Table 7.

If markets are relatively integrated, or production shocks are relatively minor, localized production shocks should not affect market prices. For most food groups, there is no significant relationship between climate deviations during the agricultural season and local prices.

Besides, most estimates of the effect are relatively small. Although for a few commodities climate deviations had a weak impact on prices, the exclusion restriction is not violated through the transmission of production shocks on commodity prices. Hence, the hypothesis of variation in climate has a significant effect on production and dietary diversity is failed to reject.

Conclusions

The discussion about the interlinkages of agriculture and food consumption and agricultural pathways to increase nutrition is likely to occur through either effects on income or the increased consumption of own-produced food. For the impact of agricultural income and production diversity on dietary diversity, we used agricultural revenue and the variability in rainfall and in degree days. The variability of the climate is shown to have different effects on revenue versus variability in crop production. Historical variations in rainfall have statistically significant effects on agricultural revenue and production diversity. The low dietary diversity and elasticity of agricultural revenue demonstrate that farmers are growing more food crops to meet their food consumption requirements rather than for commercial purposes.

The study estimated the major effects of agricultural revenue and production diversity on dietary diversity: the effect of agricultural revenue on dietary diversity is smaller than that of the production diversity of farm households. The dietary diversity–production elasticities imply that an increase of 1% in agricultural revenue increases dietary diversity by 1.03% and that an increase of 1% in production diversity increases dietary diversity by 1.76%. We found that production significantly affects household dietary diversity, and that the influence of agriculture revenue on the diet is limited.

The intra-household role in production decisions and its effect on household consumption could be investigated in future work. Farmers do not change their decision to produce crops during or across the agricultural season, so future research could investigate when farmers choose to diversify into producing foods not normally consumed in local diets that meet the population's macronutrient or micronutrient needs. This would yield insights that would help policymakers design agricultural interventions that could be expected to have larger nutritional effects. Further, the policy intervention should target—beyond augmenting the income of agricultural households—at improving the nutrition of agricultural households to be broader than income.

References

Bardhan, P, and C Udry. 1999. *Development Microeconomics*. Oxford University Press, New York. https://doi.org/10.1002/1099-1328(200010)12:7<1050::AID-JID676>3.0.CO;2-5

Barnum, H, and L Squire. 1979. An econometric application of the theory of the farm household. *Journal of Development Economics* 6: 79–102. https://doi.org/10.1016/0304-3878(79)90037-3

Birthal, P S, M D Tajuddin Khan, D S Negi, and Shaily Agarwal. 2014. Impact of climate change on yields of major food crops in India: Implications for food security. *Agricultural Economics Research Review* **27** (2): 145–155. doi: 10.5958/0974-0279.2014.00019.6

Chayanov, A K. 1966. *The Theory of the Peasant Economy*. Homewood, IL:Irwin. https://growthecon.com/assets/papers/alexander_chayanov_the_theory_of_peasant_economy.pdf

Cheteni, P, K Yohane, and M Gisele. 2020. Exploring food security and household dietary diversity in the Eastern Cape Province, South Africa. *Sustainability* 12, 1851. doi:10.3390/su12051851

Conley, T, and C Udry. 2010. Learning about a new technology: Pineapple in Ghana. *American Economic Review* 100: 35–69. doi:10.1257/aer.100.1.35

Das, U, and S Ghosh. 2019. Contrasting resilience of agriculture to climate change in coastal and noncoastal districts of Odisha. *Indian Journal of Agricultural Sciences* 89: 769–74. 10.1007/s00704-019-03061-x

Dillon, A, M Kevin, and O Gbemisola. 2015. Agricultural production, dietary diversity and climate variability. *Journal of Development Studies 51*. 10.1080/00220388.2015.1018902

Fafchamps, M. 1992. Cash crop production, food price volatility and rural market integration in the third world. *American Journal of Agricultural Economics* 74: 90–99. doi:10.2307/1242993

Hatfield, J, K Boote, P Fay, L Hahn, C Izaurralde, B A Kimball, and D Wolfe. 2008. *Agriculture*. In Backlund P, A Janetos, and D Schimel (eds.) *The effects of climate change on agriculture, land resources, water resources and biodiversity*. Washington, DC: US Climate Change Science Program and the Subcommittee on Global Change Research, pp.21–74. https://www.fs.fed.us/rm/pubs_other/rmrs_2008_backlund_p003.pdf

Jacoby, H, and S Emanuel. 1997. Risk financial markets and human capital in a developing country. *Review of Economic Studies* 64: 311–35. doi:10.2307/2971716

Jones, A D, A Shrinivas, and K R Bezner. 2014. Farm production diversity is associated with greater household dietary diversity in Malawi: findings from nationally representative data. *Food Policy* 46: 1–12. doi:10.1016/j.foodpol.2014.02.001

Kaboski, J P, and R M Townsend. 2011. A structural evaluation of a large scale quasi experimental microfinance initiative. *Econometrica* 79: 1357–1406. doi:10.3982/ECTA7079

Kaur, S. 2019. Nominal wage rigidity in village labor markets. *American Economic Review* 109: 3585–3616. doi: 10.1257/aer.20141625

Kavitha, K, P Soumitra, and R Padmaja. 2016. Understanding the linkages between crop diversity and household dietary diversity in the semi-arid regions of India. *Agricultural Economics Research Review* 29 (Conference Number): 129–137. doi: 10.5958/0974-0279.2016.00040.9

Khed, V, V Saravanakumar, and K B Umesh. 2018. Does farm size explain food consumption pattern? evidence from semi-arid regions of India. *Agricultural Economics Research Review* 31 (Conference Number): 47–55. doi:10.5958/0974-0279.2018.00021.6

Kumara, A, S Saroja, R K P Singh, and J Shiv. 2016. Agricultural diversity, dietary diversity and nutritional intake: an evidence on inter-linkages from village level studies in eastern India. *Agricultural Economics Research Review* 29 (Conference Number): 15–29. doi: 10.5958/0974-0279.2016.00030.6

Nayak, C, and C R Kumar. 2019. Crop diversification in Odisha: an analysis based on panel data. *Agricultural Economics Research Review* 32 (1). doi:10.22004/ag.econ.292204

Rangel, M, and T Duncan. 2015. Gender, production and consumption: allocative efficiency within farm households. International Food Policy Research Institute Discussion Paper 01195. http://ibread.org/bread/sites/default/files/0413conf/rangel.pdf

Sekabira, H, and N Shamim. 2020. Farm production diversity: is it important for dietary diversity?: panel data evidence from Uganda. *Sustainability* 12, 1028. doi:10.3390/su12031028

Shinoj, P, A Kumar, M C S Bantilan, and P K Joshi. 2015. Food consumption patterns and dietary diversity in eastern India: evidence from village level studies (VLS). *Food Security* 7: 1031–1042. DOI 10.1007/s12571-015-0493-2

Sibhatu, K T, V V Krishna, and Q Matin 2015 Production diversity and dietary diversity in smallholder farm households. *PNAS* 112: 10657–10662. http://www.pnas.org/cgi/doi/10.1073/pnas.1510982112

Singh, I, L Squire, and J Strauss. 1986. *Agricultural Household Models: Extensions, Applications and Policy*. Johns Hopkins University Press, Baltimore, MD. http://documents1.worldbank.org/curated/en/621291468739297175/pdf/multi-page.pdf

Strauss, J. 1982. Determinants of food consumption in rural Sierra Leone: application of the quadratic expenditure system to the consumption-leisure component of a household-firm model. *Journal of Development Economics* 11: 327–353. https://doi.org/10.1016/0304-3878(82)90010-4

Walker, T S, and J G Ryan. 1990. *Village and Household Economies in India's Semi-arid Tropics*. The Johns Hopkins University Press, Baltimore and London. http://oar.icrisat.org/485/1/RA_00151.pdf

Appendix

Table A1 Mean and standard deviation of climate variables, 1990–2014

Parameters	Village level
Annual temperature (°C)	26.20 (1.20)
Maximum temperature (°C)	32.86 (1.35)
Minimum temperature (°C)	20.54 (1.75)
Rabi temperature (°C)	23.59(1.39)
Kharif temperature (°C)	25.88(1.60)
Annual rainfall (mm)	842.36(281.04)
Rabi rainfall (mm)	60.54(75.27)
Kharif rainfall (mm)	614.54(246.02)
Rainfall days (number)	67.45(17.12)

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An economic assessment of the food security of households in the rural–urban interface of Bangalore

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Abstract The study aims to assess the food security status of households in the north and south transects along the rural–urban interface of Bangalore. Based on the recommended daily calorie intake, 72.2% of the households in the north transect and 68.6% in the south transect were food-secure. In both transects, the proportion of food-secure households was lower for agricultural households than for others. To improve food security, especially in rural areas, employment and income opportunities are needed in agriculture, and infrastructure and small-scale industries are needed to create employment and income opportunities in off-farm activities.

Keywords Food security, rural–urban interface, small-scale industries

JEL codes C25, C55, C88, I15, Q12

The World Food Summit (FAO 1996) considers that food security is achieved when all people at all times have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 2004). Food security is a major concern of policy, economic, and political debate worldwide as all countries want to ensure that all their citizens are food-secure for not only survival but also for economic development. Rising food prices affect the poor and food shortages and high prices lead to instability within nations and, potentially, conflict between them (Emerson 2011). Rapid urbanization has widespread implications for food security, nutrition, agriculture value chains, and livelihoods. Attention is due to low- and middle-income countries as these contribute to 67% of the world's urban population and the issues of food and nutritional security are most pressing (David et al. 2010). Many countries have launched programmes to achieve food security, but this goal is often thwarted by external factors. In Afghanistan, for instance, a rapid rise in wheat prices led to a fall in food consumption, calorie and protein intake, and dietary diversity; households[1] moved away from micronutrient-rich meat products to staples; and, as a result, urban and rural household food security declined (D'Souza 2008).

Over the past decades, agricultural production in India has increased considerably, especially of rice and wheat, the staple food crops. The per capita availability of food grains, and the physical access of households to food in different parts of India, have improved, too (Acharya 2009). Incomes have risen significantly, and the real expenditure on food has fallen, as India has implemented a slew of food security, welfare, and other programmes for different sections of the society, including women and children.

[1] A group of persons normally living together and eating food from a common kitchen constitutes a household. The qualification 'normally' extends to cover only temporary stay away but not temporary visitors in the group. Thus, a household member residing in a hostel is not counted, but a resident employee or domestic servant or paying guest (but not a tenant) is included in the employer or host's household. The total count of persons in a household is the household size.

However, India is one of the most 'undernourished' countries worldwide, according to its National Family Health Survey; calorie consumption, and the per capita availability of food grains, has been declining since 1987, and the percentage of underweight among children has remained constant between 1998 and 2006. The nutritional status of women and adolescent girls, who form more than 50% of the population, is crucial, as undernutrition in women leads to low birth weight and malnutrition among children. Despite rising income levels and employment opportunities—food and nutritional insecurity persists, especially among the women in the family, and this phenomenon appears to be more common in rural areas than in urban areas.

This study was undertaken in the rural–urban interface of Bangalore to study the extent and factors of food insecurity.

Methodology

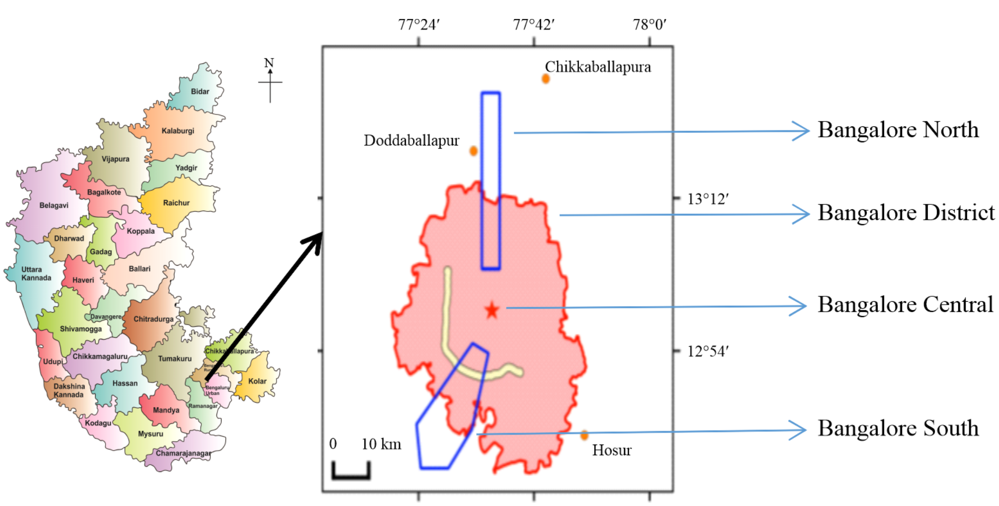
The study assesses the food security status of households in the rural–urban interface of Bangalore. The study area was divided into the northern transect (N-transect), a rectangular stripe of land 5 km wide and 50 km long. The lower part of this transect cuts into urban Bangalore and the upper part contains rural villages. The southern transect (S-transect) is a polygon covering a total area of 300 sq km; Vidhana Soudha, located in the city centre, was taken as the reference point (Figure 1).

Each transect was subdivided into the rural, transition, and urban gradients based on the logic of the Urban–Rural Index (URI). A simplified Survey Stratification Index (SSI) was developed, where the SSI refers to the linear distance between the village centre and the city centre (Hoffman et al. 2017). Building density and distance were investigated separately before they were combined to calculate the SSI.

The lottery method without replacement was used to randomly select the villages in each stratum. The final list consists of approximately 30% settlements per stratum. The baseline list of households was collected from the Anganwadi centre of a chosen village. The stratified purposive random sampling method was used to select the households. The total sample of 1,275 households consisted of 616 households from the north transect of Bangalore and 656 households from the south transect (Figure 2).

Data

To address the study objectives, both primary and secondary data were used. The primary data was collected through personal interviews using a computer-assisted schedule. The interview schedule was quite exhaustive and it collected information from the respondents on all types of food items consumed. The data was analysed using descriptive statistics, food security index, and multiple linear regression model. To facilitate meaningful comparison and interpretation



Note: The red area corresponds to the districts under Bangalore's administrative authorities. The Outer Ring Road is shown in yellow. The blue contours indicate the northern and southern transects, the star marks represent the reference point (Vidhana Soudha) in the city centre.

Figure 1 Study area

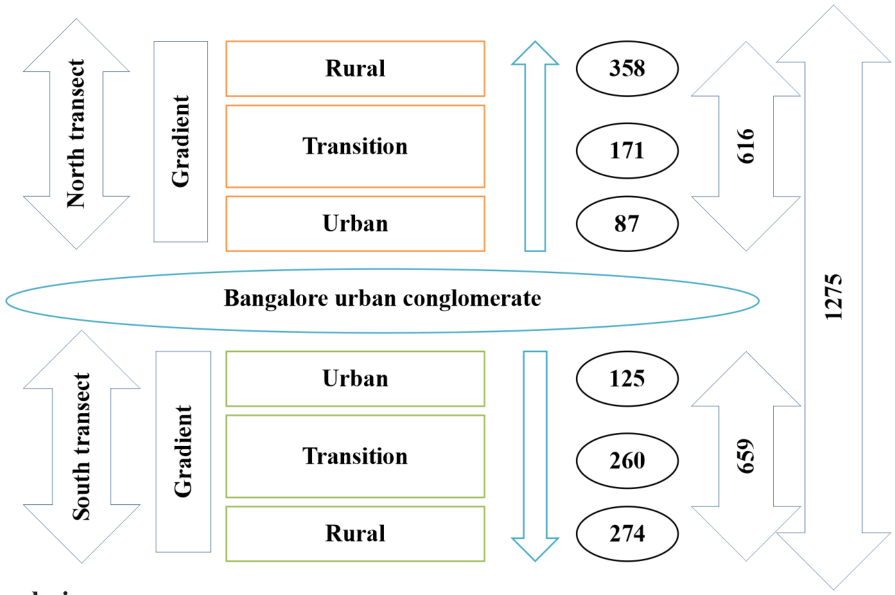


Figure 2. Sampling design

of the findings, statistical measures like percentages and averages were used. To determine the factors influencing food security, the following type of multiple linear regression model was used.

Factors influencing calorie intake

$$Y = a_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_4 + a_5 X_5 + a_6 D_1 + a_7 D_2 + a_8 D_3 + m \quad \ldots(1)$$

Where,

Y = Calorie intake (kcal per capita per day)

X_1 = Age (years)

X_2 = Education (no. of years)

X_3 = Family size (no.)

X_4 = Land holding (ha)

X_5 = Per capita income (INR per month)

D_1 = Gender (1if male, 0 otherwise)

D_2 = Urban (1 if place of residence is urban, 0 otherwise)

D_3 = Transition (1 if place of residence is transition, 0 otherwise)

a_i = Regression coefficients for independent variables defined above for i = 1 to 8.

m = Random disturbance term

Factors influencing food security

$$Y = a_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_4 + a_5 X_5 + a_6 D_1 + a_7 D_2 + a_8 D_3 + m \quad \ldots(2)$$

Where,

Y = Food Security Index (FSI)

X_1 = Family size (no.)

X_2 = Per capita income (INR per month)

X_3 = Employment in agriculture and allied (person-days per year)

X_4 = Off-farm employment (person-days per year)

X_5 = Non-farm employment (person-days per year)

D_1 = Urban (1 = if place of residence is urban and '0' otherwise)

D_2 = Transition (1 = if place of residence is transition, and '0'otherwise)

D_3 = North transect (1 = if place of residence is in north transect and '0' otherwise)

a_i = Regression coefficients for independent variables defined above for i = 1 to 8

m = Random disturbance term

For examining the food security status of households, the information on the quantity of food items consumed was recorded based on a 14-day recall period. Various aspects related to per capita food intake was probed. The data were analysed using the STATA software package.

Results and discussion

Socio-economic characteristics of the sample respondents

The socio-economic characteristics (age, education, family size, and average landholding size) are presented below. The distribution of sample respondents by age is given in Table 1. The results show that in the north transect the average age of respondents was 47 years in the rural and transition areas and 43 years in urban areas. In the transition areas, 44% of the respondents were in the 50+ age group; 33% were in the 35–50 age group and 23% in the <35 age group.

With respect to literacy rate, when we move from rural to urban areas, the percentage of illiteracy decreases from 31% to 20% in the north and from 36% to 27% in the south. The educational status of respondents in urban areas was better than in rural and transition areas because the living standards and educational facilities were better. The results showed that there was no statistically significant difference among respondents across all the gradients (rural, transition, and urban) and transects. The family size averaged about five members across gradients and transects, and the difference was statistically non-significant.

In the north transect the landholding size averaged 1.93 ha in rural areas, 1.77 ha in transition areas, and 4.64 ha in urban areas. In the south transect the landholding size averaged 1.83 ha in rural areas, 1.91 ha in transition areas, and 1.08 ha in urban areas. The mean difference in landholding size was found statistically significant across the gradients but statistically non-significant in the south transect.

The average rainfed area was 3.80 ha in urban areas, 0.8 ha in rural areas, and 0.7 ha in transition areas; however, the difference was statistically non-significant. In the north transect the average irrigated area was 1.13 ha in rural areas, 1.07 ha in transition areas, and 0.84 ha in urban areas. Only a few farmers practise agriculture in the urban areas in both transects, and most of them cultivate fruit crops, forest trees, and a small quantity of ragi for their own consumption.

Household calorie intake

The actual calorie intake was higher in rural areas than in transition and urban areas (Table 2). The Recommended Dietary Allowances[2] (RDA) are 2,730 kcal per consumption unit[3] (CU) per day for rural areas and 2,320 kcal per CU per day for urban areas (Indian Council of Medical Research 2010). Across different gradients, the calorie intake in the north transect was 3,125 kcal per CU per day in rural areas, 2,986 kcal per CU per day in transition areas, and 2,786 kcal per CU per day in urban areas. In the south transect the calorie intake was 3,089 kcal per CU per day in rural areas, 3,055 kcal per CU per day in transition areas, and 2,758 kcal per CU per day in urban areas. In both the transects, the actual calorie intake and the proportion of actual calorie intake to the recommended intake was higher in rural areas than in urban and transition areas.

Factors influencing calorie intake

The factors influencing calorie intake across the rural–urban interface of Bangalore are elucidated in Table 3. The education level and family size negatively and significant influenced calorie intake, whereas landholding size and the urban dummy had a positive and significant influence. The results are in line with the study conducted by Kumar et al. (2016).

Food security status of households

The food security status of households is presented in Table 4. The recommended daily calorie intake defines the food security line, and consumption below the minimum level of calorie requirement indicates food insecurity. Based on the recommended daily calorie intake, 72.2% of the households in the north transect and 68.6% in the south transect, or most households in the study area, were food-secure.

Factors influencing food security

We use the multiple linear regression model to examine the impact of several variables—family size,

[2] The Recommended Dietary Allowances (RDA) are estimates of the intakes of nutrients which individuals in a population group need to consume to ensure that the physiological needs of all subjects in that population are met (ICMR 2010).

[3] The energy consumption of an average male doing sedentary work is taken as one consumption unit (CU). The other coefficients are worked out on the basis of calorie requirements relative to that of a sedentary adult man.

Table 1 Socio-economic characters of sample respondents in the rural–urban interface of Bangalore

Particulars	North transect			Test of significance	South transect			Test of significance
	Rural (n=358)	Transition (n=171)	Urban (n=87)		Rural (n=274)	Transition (n=260)	Urban (n=125)	
I. Age group (Head of the family)								
a. Average age (years)	47	47	43		48	46	41	
b. Below 35 years (number)	64 (18.44)	38 (23.03)	26 (30.59)	X^2=30.2*	33 (14.29)	44 (17.81)	42 (35.59)	
c. 35–50 years (number)	134 (38.62)	55 (33.33)	33 (38.82)		92 (39.83)	107 (43.32)	47 (39.83)	Chi^2= 6.43^{NS}
d. Above 50 years (number)	149 (42.94)	72 (43.64)	26 (30.59)		106 (45.89)	96 (38.87)	29 (24.58)	
2. Literacy (Education)								
a. Primary (number)	88 (25.36)	46 (27.88)	17 (20.00)	X^2=7.48^{NS}	50 (22.22)	59 (25.12)	16 (13.64)	
b. High school (number)	108 (31.12)	50 (30.30)	23 (27.06)		57 (25.93)	71 (29.86)	40 (33.64)	
c. College (number)	44 (12.68)	29 (17.58)	28 (32.94)		35 (15.84)	29 (11.85)	30 (25.45)	Chi^2= 3.40^{NS}
d. Illiterate (number)	107 (30.84)	40 (24.24)	17 (20.00)		89 (35.98)	88 (33.18)	32 (27.27)	
III. Average family size (number)	5	5	5	F=0.80^{NS}	5	5	4	F= 1.00^{NS}
IV. Land holding size (ha)								
a. No. of farmers	257	91	2	X^2=708*	166	114	4	Chi^2= 572*
b. Average rainfed area (ha)	0.80 (41.45)	0.70 (39.55)	3.80 (81.89)	F=0.33^{NS}	0.90 (49.18)	0.80 (41.88)	-	F= 3.15**
c. Average irrigated area (ha)	1.13 (58.55)	1.07 (60.45)	0.84 (18.10)	F=39.68*	0.93 (50.81)	1.21 (63.35)	1.08 (100.00)	F= 0.15^{NS}
d. Average landholding (ha)	1.93	1.77	4.64	F=5.67*	1.83	1.91	1.08	F=1.54^{NS}

Note: Figures in parentheses represent percentages

Table 2 Calorie intake of respondents as per the RDA in the rural–urban interface of Bangalore

Area	Actual calorie intake (kcal/CU/day)		Recommended calorie intake based on ICMR (kcal/capita/day)	Difference (kcal/capita/day)	
	North	South		North	South
Rural	3,125	3,089	2,730	395 (114.4)	359 (113.0)
Transition	2,986	3,055	2,730	256 (109.4)	325 (111.9)
Urban	2,786	2,758	2,320	466 (120.1)	438 (118.9)

Source: Indian Council of Medical Research, 2010; RDA-Recommended Dietary Allowance
Note: Figures in parentheses indicate percentages
Difference=Actual calorie intake – Recommended calorie intake

Table 3 Factors influencing calorie intake across the rural–urban interface of Bangalore using multiple linear regression analysis
[Dependent variable= calorie intake (kcal/capita/month)] (n=1,275)

Variables	Coefficients	t value
Age (years)	–3.957	–1.128
Education (no. of years)	–17.125***	–1.950
Family size (number)	–62.72*	–3.58
Land holding (ha)	83.14***	1.93
Per capita income (INR per month)	0.001	1.30
Gender (D_1)	144.190	1.52
Urban (D_2)	174.116***	1.87
Transition (D_3)	27.130	0.40
Constant	1,028*	0.00
R^2 value	0.47	
F value	8.61*	

Note: 1. *Significant at 1%, ***significant at 10%
2. Gender (D_1): 0= female & 1= male,
3. Urban (D_2): 1=urban, otherwise '0'
4. Transition (D_3): 1= transition, otherwise '0'

landholding size, per capita income, dummy for urban, dummy for transition, and transect dummy—on the food security index score (Table 5). The estimates of the determinants of food security reveal that the variables included in the model explain up to 42% of the variation in food security; the calculated F value was statistically significant. The model included several dependent variables; those that significantly and positively influenced the food security status are employment from agriculture and non-farm sources, per capita income, and urban dummy. Family size negatively influenced food security. The per capita food availability declines as family size increases due to population growth (Mannaf and Uddin 2012); hence, if a family is large, the household is likely to experience food insecurity.

Employment sources and food security status

The employment opportunities and food security status across the rural–urban interface of the north transect (Table 6) indicate that the non-farm sector generated the highest number of person-days of employment. The person-days of employment from all the sectors

Table 4 Food security status of households across the rural–urban interface of Bangalore

Particulars	North transect				South transect			
	Rural	Transition	Urban	Total	Rural	Transition	Urban	Total
Food-secure households (number)	234	135	76	445	170	180	102	452
Percentage of households food-secure (%)	65.36	78.95	87.36	72.24	62.04	69.23	81.60	68.59

Table 5 Factors influencing food security across rural-urban interface of Bangalore using multiple linear regression analysis

[Dependent variable= Food Security Index (FSI)]

(n=1,275)

Variables	Coefficients	P value
Family size (number)	-0.076*	0.000
Per capita income (INR per month)	0.0020**	0.049
Employment generation (person-days/year)		
a. Agriculture and allied	0.0006*	0.003
b. Off-farm	0.0002	0.051
c. Non-farm	0.0005*	0.000
Urban (D_1)	0.095**	0.045
Transition (D_2)	0.087	0.061
North transect (D_3)	0.064	0.084
Constant	1.20*	0.000
R^2 value	0.42	
F value	15.10*	

Note: 1. *significant at 1%, **significant at 5%
2. Urban (D_1): 1=urban, otherwise '0',
3. Transition (D_2): 1=transition, otherwise '0',
4. North transect (D_3): 1= north transect, otherwise '0'

averaged 269 person-days in the urban gradient (the highest), 255 person-days in the transition gradient, and 252 person-days in the transition gradient. Almost all the family members (except children and students) in urban areas were employed in the formal or informal sector; hence, the average person-days was higher in urban areas than in transition and rural areas. Most households in rural areas were employed in the non-farm sector and in transition and urban areas in the government sector. About 40%, 53% and 63% of the employment was generated from the non-farm sector in, respectively, the rural, transition, and urban gradients. The employment generated from the agriculture sector was 32%, 15%, and 0.50% in, respectively, the rural, transition, and urban gradients.

The monthly or annual income generated in the public sector was higher than in the agriculture sector; therefore, in all the three gradients, the percentage of food-secure households was greater for households employed in the government sector, and they enjoyed better food security. While it was the least in agriculture sector.

About 58%, 63%, and 68% of the households in, respectively, the rural, transition, and urban gradients

Table 6 Sources of employment and status of food security in north transect

Particulars	Rural				Transition				Urban			
	Person-days/ person/year	Number of persons	Employment generation (%)	Food-secure households (%) (n=160)	Person-days/ person/year	Number of persons	Employment generation (%)	Food-secure households (%)(n=181)	Person-days/ person/year	Number of persons	Employment generation (%)	Food-secure households (%) (n=91)
Agriculture	215	127	31.83	50.79	192	71	15.40	53.19	98	2	0.50	96.02
Agriculture labourer	280	24	7.83	45.83	230	31	8.06	51.61	-	-	-	-
Livestock	138	69	11.10	52.17	165	38	7.08	52.63	179	15	6.85	60.00
Off-farm	295	16	5.50	56.25	297	36	12.08	58.33	296	35	26.43	65.71
Non-farm	315	108	39.65	58.33	326	143	52.67	62.93	302	82	63.17	68.29
Govt. employee	270	13	4.09	69.23	320	13	4.70	70.33	300	4	3.06	75.00

employed in the non-farm sector were food-secure. In all the sectors of employment, the number of food-secure households increased from rural to urban gradients. In 2009–10, just under 30% of the urban workforce in India was informally employed, of which 50% were self-employed (street vendors, petty shop owners, tailors, business people, etc.), and 50% were wage employees (home-based workers, waste-pickers, helpers, newspaper distributors) (Chen and Raveendran 2011).

In the south transect, agriculture sector was the major source of employment for rural households (33%) in the agriculture-dominated areas of Bangalore (Table 7), where the influence of urbanization was lower than in transition and urban areas. In transition areas the agriculture sector was the second major source of employment (23%). The non-farm sector constituted more than 30% of the total employment generated in all the three gradients and generated the most employment in the transition (38%) and urban (49%) gradients.

Livestock contributed to 13%, 14%, and 11% of the total employment in, respectively, the rural, transition, and urban gradients. The number of person-days of employment averaged 296 in the urban gradient (the highest), 253 person-days in the transition gradient, and 253 person-days in the rural gradient. More than 60% of the households in all the three gradients employed in the government sector were food-secure (64% in the rural gradient, 67% in the transition gradient, and 78% in the urban gradient). The proportion of food-secure households was low for the households employed in the agriculture sector and as agriculture labour when compared to other sectors, because farm income or farm produce depends on the climate, but the income of people employed in the government sector and in off-farm and non-farm activity is stable and regular.

Conclusions

This study investigated the extent and factors of food insecurity in the rural–urban interface of Bangalore. The study presupposed that, despite rising income levels and employment opportunities, food and nutritional insecurity persists, especially among women in the family, and this phenomenon appears to be more common in rural areas than in urban areas. Based on

Table 7 Sources of employment and status of food security in south transect

Particulars	Rural				Transition				Urban			
	Person-days/ person/year	Number of persons	Employment generation (%)	Food-secure households (%) (n=260)	Person-days/ person/year	Number of persons	Employment generation (%)	Food-secure households (%)(n=132)	Person-days/ person/year	Number of persons	Employment generation (%)	Food-secure households (%) (n=62)
Agriculture	218	154	33.03	51.09	222	59	22.87	55.93	65	4	0.84	92.26
Agriculture labourer	250	44	10.82	47.72	267	17	7.93	52.94	-	-		-
Livestock	143	95	13.36	58.94	172	47	14.12	57.44	184	18	10.71	61.11
Off-farm	313	28	8.62	57.14	278	23	11.17	60.86	335	27	29.24	66.66
Non-farm	310	102	31.11	58.16	303	72	38.10	56.94	316	48	49.03	54.16
Govt. employee	283	11	3.06	63.64	278	12	5.83	66.66	350	9	10.18	77.77

Note: 1. Off-farm= flour mill, flower shop, fruit shop, dairy care taker, poultry farm, etc.
2. Non-farm= Tailor, newspaper distributer, driver, real estate, clothing store, shop keeper, phone retailer, etc.

the recommended daily calorie intake, 72.2% of the households in the north transect and 68.6% of the households in the south transect, or most households in the study area, were food-secure. The variables such as employment from agriculture and non-farm sources, per capita income, and urban dummy are significant and they positively influence food security. The proportion of food-secure households was lower for households employed in the agriculture sector and as agriculture labour than in other sectors in both the transects. Food insecurity exists, but it is low.

To improve the food security status in rural areas, employment and income opportunities in agriculture and off-farm activities need to be created with suitable infrastructure and small-scale industries.

The central and state governments sponsor many food security programmes, but food insecurity persists. The government should consider using the public distribution system to make various food items available and creating employment opportunities that generate an income sufficient to buy the necessary components of balanced diet and minimize food insecurity.

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References

Acharya, S S. 2009. Food security and Indian agriculture: Policies, production performance and marketing environment. *Agricultural Economics Research Review,* 22, 1–19.

Chen, M A, and G Raveendran. 2011. Urban employment in India: Recent trends and patterns. *Women in Informal Employment Globalization and Organizing (WIEGO)*, 1–17.

D’Souza, A. 2008. Rising food prices and declining food security evidence from Afghanistan. *Amber Waves* 9 (3): 26–33.

David, S, M Gordon, and C Tacoli. 2010. Urbanization and its implications for food and farming. *Phil. Trans. R. Soc. B.*, 365: 2809–2820.

Emerson, C. 2011. Food Security in the Asian Century. *Conference conducted by the Crawford Fund for International Agricultural Research, Parliament House, Canberra*, Australia, 14–16.

Food and Agriculture Organization 2004. The state of food insecurity in the world: Monitoring progress toward the food summit on Millennium Development Goals. *Food and Agricultural Organization of the United Nations*, Rome.

Food and Agriculture Organization 2009. World Summit on Food Security, *World Food Summit*, Rome, 16–18 Nov. Available at *http://www.fao.org*.

Hoffmann E, Jose M, Nölke N, and Möckel T. 2017. Construction and use of a simple index of urbanization in the rural–urban interface of Bangalore, India. *Sustainability*, 9 (11): 1–21.

Indian Council of Medical Research. 2010. Revised RDA for Indians. *Report of the Expert Group of the ICMR*-NIN, Hyderabad, India.

Kumar, A, S Saroja, R K P Singh, and S Jee. 2016. Agricultural diversity, dietary diversity and nutritional intake: An evidence on inter-linkages from village level studies in Eastern India. *Agricultural Economics Research Review*, 29: 15–29.

Mannaf, M, and T M Uddin. 2012. Socio-economic factors influencing food security status of maize growing households in selected areas of Bogra District. *Bangladesh Journal of Agricultural Economics*, 35 (1&2): 177–187.

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DOI: 10.5958/0974-0279.2020.00017.8

Advancing with fertilizers in Indian agriculture: trends, challenges, and research priorities

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Abstract We study the national and state-level fertilizer use trends using time series data, the influence of key policies on consumption using interrupted time series analysis, and the current research priorities using bibliometric analysis. The Retention Price Scheme raised long-term consumption; decontrol policy reduced consumption, but the concession scheme reversed the reduction; and the Nutrient Based Subsidy scheme has been reducing consumption. Continuing to formulate fertilizer policies based on research evidence, and implementing these, will help meet targets.

Keywords Fertilizer nutrient, fertilizer policy, interrupted time series, bibliometric analysis

JEL codes Q01, Q18, Q58

India is the second largest producer and consumer of fertilizers in the world—after China. In 2017, India consumed 17 million tonnes of nitrogen, 6.9 million tonnes of phosphorus, and 2.8 million tonnes of potash (Fertilizer Association of India 2019). Fertilizer use is governed by government policies (Gulati and Banerjee 2015): the Fertilizer Control Order, Retention Price Scheme, Nutrient Based Subsidy, New Pricing Scheme, decontrol, nutrient-based pricing, joint ventures abroad, neem coating of urea, Direct Benefit Transfer system for fertilizer subsidy distribution, etc. (Praveen 2017).

Fertilizer use has helped improve crop yield (Kishore et al. 2013), and the process of improvement is continual; however, its environmental effects—eutrophication, emission of greenhouse gases, and distortion in the soil nutrient balance (Adhya et al. 2016; Kanter et al. 2015)—have raised concerns over sustainability (Patra et al. 2016). As the population pressure increases and the resources available for farming decrease, increasing fertilizer use may not be enough in the future; improving the efficiency of fertilizer use is imperative (Hossain and Singh 2000).

To frame effective policy, policymakers need research evidence (Puttick 2011). The research regime in fertilizers has achieved considerable progress in areas such as fertilizer application rates, nutrient use efficiencies, yield enhancement due to fertilizers, time of fertilizer application, the right quantity of fertilizers for crops, and a region-specific recommendation of fertilizers (Chand and Pavithra 2015; Sharma and Thaker 2011). Considering the manifold research areas evolving within the broad topic of fertilizers, a scientific probe into the recent research trends will have great value in understanding whether our research priorities are in line with future challenges.

One way to achieve this is through bibliometrics, or the quantitative analysis of the available research evidence (Nafade et al. 2018). Bibliometric analysis can help to empirically document the volume of research into fertilizers, the direction of knowledge development, and identify the key research players (Zhang et al. 2019). We draw on the secondary data available and analyse the effect of key policies in regulating fertilizer use. We track the trends in fertilizer use at the national, state, and district level to identify the challenges in the future and formulate research priorities.

Data and methodology

We utilize the secondary data provided by the Directorate of Economics and Statistics (Agricultural Statistics at a Glance) and the Fertilizer Association of India (Fertilizer Statistics). We use QGIS to create state and district maps to visualize the spatial variation in fertilizer use.

In the interrupted time series analysis (ITSA) method, an outcome variable is observed over multiple, equally spaced periods before and after the introduction of an intervention that is expected to interrupt its level or trend (Linden and Adams 2011). The ITSA for a single period is

$$Y_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 X_t T_t + \varepsilon_t$$

where, Y_t is the aggregated outcome variable measured at each equally spaced time point t; T_t is the time since the start of the study; X_t is a dummy (indicator) variable representing the intervention (pre-intervention periods 0, otherwise 1), and $X_t T_t$ is interaction term.

β_0 represents the intercept or starting level of the outcome variable; β_1 is the slope or trajectory of the outcome variable until the introduction of the intervention; β_2 represents the change in the level of the outcome that occurs in the period immediately following the introduction of the intervention, and β_3 represents the difference between the pre-intervention and post-intervention slopes of the outcome.

To estimate the effect of important policies on fertilizer use, we use the ITSA model. The model supports the adding of factor variables. We include for the period from 1972 to 2017 several factor variables: the share of high yield variety (HYV) seeds in gross cropped area (GCA) (%),share of gross irrigated area (GIA) to GCA (%),price of N, P, and K (INR per kg), output price (INR per quintal), short-term institutional credit to agriculture (INR crore), cropping intensity (%), and fertilizer subsidy (INR crore).

We review the literature to identify the future challenges. In January 2020 we conducted a literature search for research into fertilizers in India using the ISI Web of Science. We selected articles published in English-language journals between 2010 and 2020. (We excluded all other document types.) To select studies, we used the search string (TS: ('fertilizer' OR 'fertiliser') AND CU=India). The search yielded 1,887 studies.

The software tool VOSviewer enables the visualization and easy interpretation of bibliometric data (van Eck and Waltman 2010). We used VOSviewer and knowledge mapping to carry out a bibliometric analysis of the name of author(s), year of publication, journal name, article title, and citations. To identify and map the scope and structure of the subject, we performed network analysis using the co-occurrence of author keywords and co-authorship of authors and institutions, along with which the link strengths were generated.

The fractional counting approach helps to visualize proper field-normalized results. We used it to visualize the co-occurrence network of keywords and co-authorship networks of authors, institutions, and countries.

Fertilizer use trends

India is the second largest producer of nitrogen fertilizers, urea, and diammonium phosphate (DAP) in the world and the second largest consumer of nitrogen and phosphorus fertilizers. India is the third largest producer of phosphorus fertilizers. Potash fertilizers are not produced in India, but it is the fourth largest consumer, and it depends on both production and imports to ensure that the domestic supply of fertilizers is adequate. Imports have decreased recently, especially after 2010; notwithstanding, in 2018–19, imports constituted about 38% of all fertilizers consumed, 26% of nitrogen fertilizers, and 45% of phosphorus fertilizers.

Fertilizer consumption increased from 69,000 tonnes in 1950 to 5.5 MT in 1980 and to 28 MT in 2010 and decreased by about 1 MT between 2010 and 2018 (Figure 1). Nitrogen is the highest consumed primary nutrient (65% in 2018), followed by phosphorus (25%) and potash (10%). The growth rate of fertilizer consumption peaked at 23.6% in the 1960s and declined thereafter. The growth has been negative (–0.4%)—for the first time—in this decade (2010–2018).

Nitrogen is the fertilizer that we consume the most, but in the 1950s and 1960s the growth in fertilizer

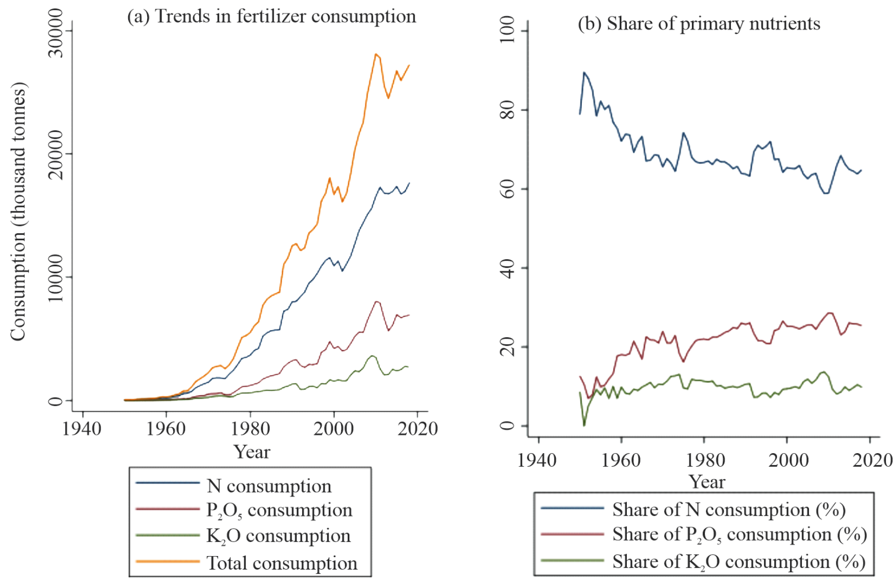

Figure 1 (a) Trends in fertilizer consumption ('000 tonnes) and (b) share of primary nutrients in total fertilizer consumption (%)

consumption was driven equally by the consumption of phosphorus and potash. In the 1960s, nitrogen consumption grew at 23%, phosphorus at 25%, and potash at 24%. The decadal growth rate in phosphorus consumption has consistently exceeded that of nitrogen since the 1980s, but the growth in potash use has been almost at par. The low growth rates this decade—0.8% (N), –1.9% (P), –3.3% (K)—indicate the beginning of a new trend in fertilizer use.

Among the states, Uttar Pradesh, Maharashtra, Madhya Pradesh, Karnataka, and Punjab were the top five fertilizer consumers. The green revolution pumped fertilizers into the cereal-centric cropping regions of the upper Indo-Gangetic Plains (IGP), and fertilizer use has long been high in these states and in southern states like Andhra Pradesh and Karnataka. However, when we analyse the state-level intensity in fertilizer use between 1980 and 2018, we can observe a transition in this pattern (Figure 2).

The northern and southern states—Punjab, Tamil Nadu, Uttar Pradesh, Karnataka, Andhra Pradesh, and Haryana, where the intensity of fertilizer use has been high, ranging from 130 kg per ha in Karnataka to more than 210 kg per ha in Punjab and Haryana—experienced the lowest growth rate in fertilizer use intensity (0.6% in Punjab, 4.5% in Haryana).

The growth rate of fertilizer use per hectare was better in the central and western states—Madhya Pradesh (5.8%), Maharashtra (4.3%), and Rajasthan (5.4%)—where the fertilizer use intensity is lower, ranging from 50 kg per ha in Rajasthan to 125 kg per ha in Maharashtra.

However, in the eastern states of Odisha, Bihar, and Assam, where fertilizer consumption has traditionally been less than in the northern and southern states, fertilizer use intensity grew at 7–8% per annum, indicating that fertilizer use is moving slowly from where it has peaked to where it has a better role to play.

The district-level fertilizer consumption maps (total consumption in tonnes and consumption in kg per hectare) points out the regional variation in fertilizer use (Figure 3). The major consumers of fertilizers are the districts in the IGP, undivided Andhra Pradesh, and Maharashtra.

Interestingly, when we check the proportion of districts (%) by the consumption of NPK per hectare, we can observe a trend supporting intensive fertilizer use. In 2000, only 7% of the districts in the country, and in 2018 about 20% of the districts, consume more than 200 kg of fertilizers per hectare. While 60% of the districts in 2018 consume more than 100 kg fertilizers per ha, only 37% did in 2000.

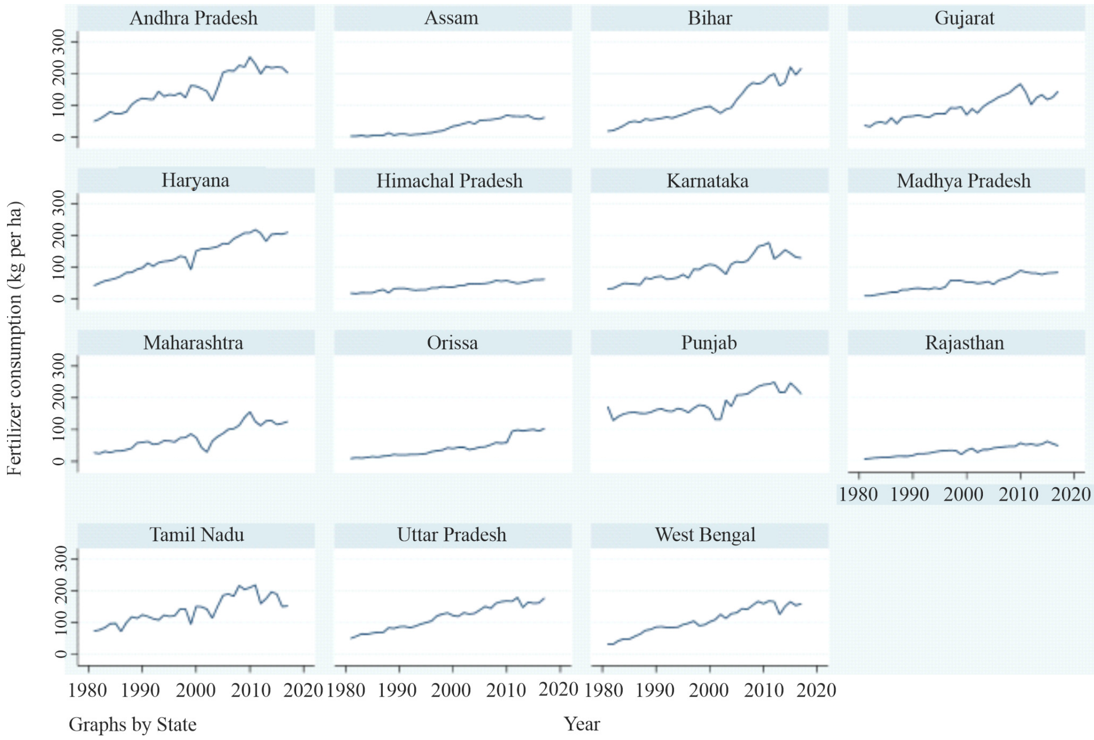

Figure 2 State-level trends in the intensity of fertilizer consumption (kg/ha) (1980-2018)

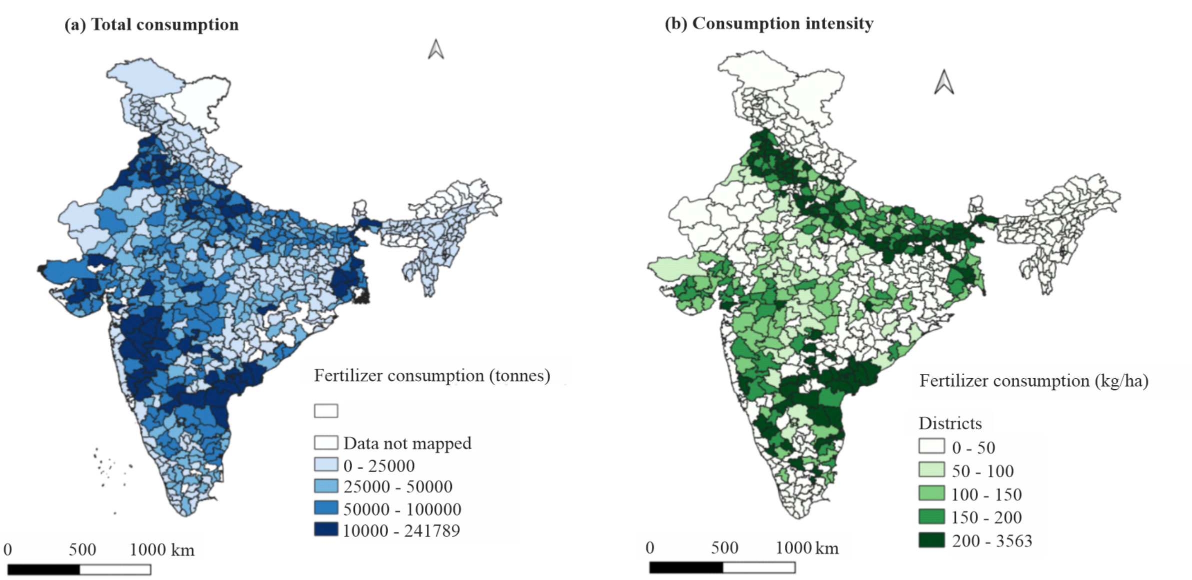

Figure 3 District level fertilizer consumption (a) total consumption in tonnes (b) consumption intensity in kg per ha (2017-18)

Effect of key policies

The Retention Price Scheme, decontrol, concession, and the Nutrient Based Subsidy were intended to directly affect nutrient consumption. We select these to test the effect of policies on fertilizer consumption. The devaluation of the rupee in 1966, and the oil price shock in 1973, made fertilizers unaffordable to Indian farmers. In 1977, the central government implemented the Retention Price Scheme, a protectionist policy that ensured each production unit a 12% post-tax return on net worth regardless of the age, location, technology, and cost of production. Cuts in the fertilizer subsidies were a part of the New Economic Policy instituted in India since 1991. To meet this end, the prices of all phosphorus and potash fertilizers were decontrolled in 1992. This reform increased fertilizer (P and K) prices and decreased consumption, to compensate which a concession scheme was announced immediately. Nitrogen fertilizers, however, remained the holy grail and enjoyed the subsidy. This led to a wide disparity in the composition of fertilizer use in the country that favoured nitrogen (Praveen 2014). The Nutrient Based Subsidy scheme was announced in 2010 to address this issue.

We carried out the ITSA separately for nitrogen, phosphorus, potash, and total fertilizer consumption (Table 1). The results suggest that the Nutrient Based Subsidy and Retention Price Scheme had a significant, long-term effect on nitrogen consumption. The Retention Price Scheme increased nitrogen consumption by 137,000 tonnes per annum, after controlling for other factors, and the Nutrient Based Subsidy decreased nitrogen consumption by 798,000 tonnes per annum. Nitrogen consumption is affected significantly by—in addition to these policies—factors like the share of gross irrigated area in gross cropped area, price of nitrogen and potash, output price, short-term institutional credit, cropping intensity, and fertilizer subsidies.

The Retention Price Scheme had an immediate negative effect on phosphorus consumption and a long-term positive effect. This may be because the Retention Price Scheme was implemented in two phases. Initially, it was introduced for nitrogen in 1977 and in 1979—after discontinuing the fixed subsidy per tonne of phosphorus—extended to phosphorus. Removing the fixed subsidy had reduced phosphorus consumption immediately, but the reduction was offset by the long-term rise in consumption (86,000 tonnes per annum). Interestingly, the decontrol of phosphorus prices could impact only an immediate negative effect on its consumption—it could not reduce consumption in the long term, because it was closely followed by the

Table 1 Fertilizer consumption as affected by key policies and control factors

Parameters	Nitrogen		Phosphorus		Potash		Total fertilizers	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient error	Standard
Trend	–47.88	131.44	56.34	115.77	–14.22	52.44	–197.03	285.96
RPS immediate effect	–188.17	243.93	–292.26**	122.58	–49.62	84.54	–82.56	502.73
RPS long-term effect	137.56**	64.74	86.71**	35.12	25.49	21.64	372.16***	114.72
Decontrol immediate effect	174.66	235.64	–965.38***	239.71	–402.40***	112.44	–890.83*	461.03
Decontrol long-term effect	–72.05	55.54	47.03	70.34	34.15	25.98	–61.57	131.61
Concession immediate effect			696.99	1432.99				
Concession long-term effect			1318.60**	517.52				
NBS immediate effect	565.31	452.87	98.03	504.57	–447.44**	170.52	1287.14	1034.41
NBS long-term effect	–798.37***	178.83	–1253.85***	239.83	–334.29***	64.46	–1790.42***	429.69
Share of HYV in GCA (%)	43.15	51.00	–29.93	43.67	11.42	19.36	92.83	108.50
Share of GIA to GCA (%)	312.86***	61.55	240.66**	105.93	71.53	43.56	553.01**	198.29
Price of N (INR/kg)	–238.63**	101.15	–168.78*	88.32	0.01	34.47	–295.72	224.07
Price of K (INR/kg)	–112.34**	54.79	–139.95	93.41	–73.29**	32.27	–388.13**	156.36
Price of P (INR/kg)	71.83	44.75	57.41	71.59	–5.03	27.42	150.80	120.99
Output price (INR/quintal)	1.11**	0.46	–1.62	2.51	0.12	0.30	0.94	0.98
Short-term institutional credit to agriculture (INR crore)	0.01**	0.01	–0.01	0.01	0.01***	0.01	0.02**	0.01
Cropping intensity (%)	140.65**	65.65	–30.01	72.38	–0.56	16.84	79.73	145.51
Fertilizer subsidy (INR crore)	0.01*	0.00	0.01	0.01	0.01*	0.01	0.03**	0.01
Constant	–22691.67**	7953.75	–721.65	9454.74	–1416.95	2417.33	–20753.45	18676.50

concession scheme, implemented in the 1979 rabi season.

A concession of INR 1,000 per tonne for DAP and murate of potash (MOP) increased the phosphorus concession by 1,318,000 tonnes per year in the long term. The Nutrient Based Subsidy, however, seemed to cut phosphorus consumption as well—by 1,253,000 tonnes per annum in the long term. The Retention Price Scheme could not affect potash consumption significantly. Decontrol reduced potash consumption immediately on introduction, but the reduction was not sustained in the long term. The Nutrient Based Subsidy reduced consumption in the short and long term.

The Retention Price Scheme achieved its target of raising consumption in the long term by making fertilizers available at cheaper rates. The government implemented the decontrol policy to reduce its subsidy burden; the policy reduced fertilizer consumption immediately after introduction, but the concession scheme that followed reversed the reduction in the long term by raising consumption.

The Nutrient Based Subsidy aims primarily to reduce the overuse of fertilizer nutrients and maintain the nutrient ratio balance in soils, and our findings show that the policy is performing along the expected lines. The Nutrient Based Subsidy reduced nitrogen consumption in the long term, but the reduction is less than in phosphorus consumption, which could pose a concern shortly.

Emerging challenges

Indian agriculture has traditionally been driven by indigenous methods that use locally regenerable materials for soil fertilization. Modern methods based on HYV seeds and chemical fertilizers were introduced only in the 1960s, by the green revolution (Ghosh 2004 a). Several other policies—like the Retention Price Scheme, Nutrient Based Subsidy, fertilizer subsidies, decontrol of P and K fertilizers, investment policies—directly affected fertilizer consumption. As fertilizer consumption continued to rise substantially, the elasticity of output to fertilizers dropped sharply (Kapur 2011). The response of crops to this changing input mix, however, varied by agroecosystem. The reduction in response by major crops to fertilizer nutrients in the different agroecosystems of the country is the first challenge to be addressed. Since fertilizer is input, the demand for fertilizer is a derived one; it depends on the use of land and other complementary inputs (such as irrigation, modern seeds, and soil quality that affects the yield response of crops to fertilizer use (Hossain and Singh 2000).

Projecting the demand for plant nutrients in the future country helps in formulating strategy for production, imports, and subsidies, and it is always a challenge. The largest share of the central government's agriculture budget is spent on fertilizer subsidies (Anuja 2015), though its relevance has been questioned repeatedly in policy circles, especially as fiscal constraints rise, and who benefits remains a matter of debate. To reduce leakage and improve efficiency, cost-effectiveness, and the delivery of fertilizers, the government introduced a Direct Benefit Transfer mechanism.

Organic fertilizers and biofertilizers are being promoted through public intervention, but farm-level adoption, and diffusion across states, is lower than the projection (Ghosh 2004b). Chemical fertilizers emit nitrous oxide and leach soil nutrients; improving the adoption of organic fertilizers and biofertilizers would reduce the environmental costs. The grand challenge is to raise food production and lower the environmental externalities by reducing fertilizer use where it is excessive and raise it where it is needed. Manoeuvring nutrient subsidies is one way, and enquiries in this line will be challenging for future researchers, as specific case studies are crucial to set the course of action.

Are the current research priorities on fertilizers in line with the challenges?

We portray the latest research trends on the topic "fertilizers" in India as explored by applying the bibliometric approach to the bibliographic data collected from Web of Science core collection. The bibliometric technique helps to find out the research trend, focus, and the most influential authors, institutions, and countries in research on a topic. We identified and extracted the details of 1,887 studies on fertilizers published between 2010 and 2020 carried out, or based, in India on India. Together these were cited 14,625 times, each item being cited 7.75 times on average.

The total citations and the sum of the times cited (Figure 4) show a steadily increasing trend, indicating the

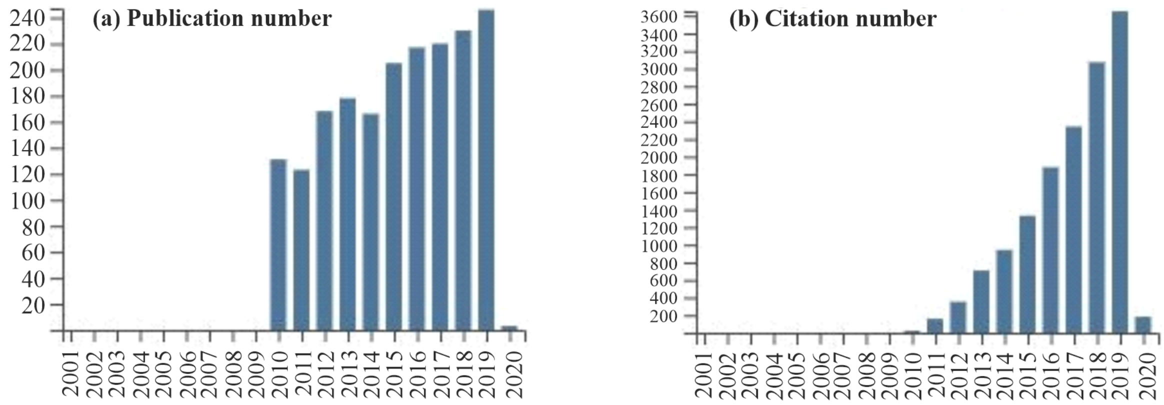

Figure 4 Research trends on fertilizers (a) number of publications (b) number of citations (2010-2020)

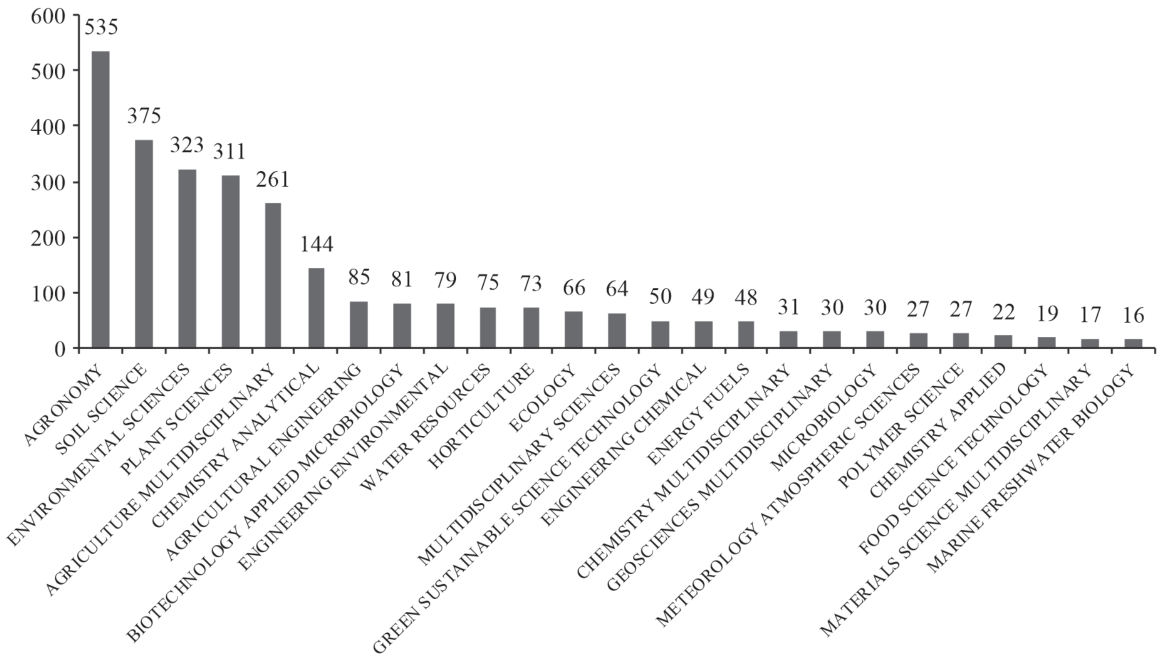

Figure 5 Subject wise number of publications

importance of the research on fertilizers. Agronomy has a 28% share in the number of publications, followed by soil science (20%), environmental science (17%), plant sciences (16%), and agriculture multidisciplinary (13%) (Figure 5). Of all the studies on fertilizers in the 10-year period (2010–2020), 144 were cited more than 25 times, 37 more than 50 times, and 3 studies were cited more than 100 times. The high level of citations points to the research attention that good publications on fertilizers attract.

Influential articles and journals

The articles that are cited the most are identified as being influential (Table 2). The most widely cited Indian studies on fertilizers published between 2010 and 2020 deal primarily with the treatment of the fertilizer industry wastes, greenhouse gas emissions, conservation agriculture, climate change mitigation, the effect of fertilizers on soil organic carbon, and the utilization of biofertilizers for biofortification.

We consider an article cited more than 25 times 'highly cited'. Table 3 presents the bibliometric details of the influential journals publishing highly cited articles on fertilizers. The lead journals identified are *Field Crops Research*, *Soil & Tillage Research*, *Bioresource Technology*, *Plant and Soil*, and *Nutrient Cycling in Agroecosystems*.

Table 2 Most influential articles

Title	Authors	Journal	Year	Total citations	Average per year
Adsorption studies on the removal of hexavalent chromium from aqueous solution using a low-cost fertilizer industry waste material	Gupta, Vinod K; Rastogi, Arshi; Nayak, Arunima	*Journal of Colloid and Interface Science*	2010	413	37.55
Effects of rice straw and nitrogen fertilization on greenhouse gas emissions and carbon storage in tropical flooded soil planted with rice	Bhattacharyya, P; Roy, K S; Neogi, S; Adhya, T K; Rao, K S; Manna, M C	*Soil & Tillage Research*	2012	119	13.22
Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agroecosystems?	Powlson, David S; Stirling, Clare M; Thierfelder, Christian; White, Rodger P; Jat, M L	*Agriculture Ecosystems & Environment*	2016	93	18.60
Long-term manuring and fertilizer effects on depletion of soil organic carbon stocks under pearl millet-cluster bean-castor rotation in western India	Srinivasarao, Ch; Venkateswarlu, B; Lal, R; Singh, A K; Kundu, S; Vittal, K P R; Patel, J J; Patel, M M	*Land Degradation & Development*	2014	92	13.14
Biofortification of wheat through inoculation of plant growth-promoting rhizobacteria and cyanobacteria	Rana, Anuj; Joshi, Monica; Prasanna, Radha; Shivay, Yashbir Singh; Nain, Lata	*European Journal of Soil Biology*	2012	83	9.22

Table 3 Top 10 journals publishing highly cited articles

Journal	Number of highly cited articles	Total citations of highly cited articles	Citation per highly cited article	Journal impact factor
Field Crops Research	11	450	40.9	4.308
Soil & Tillage Research	10	555	55.5	4.601
Bioresource Technology	9	543	60.3	7.539
Plant and Soil	7	377	53.9	3.299
Nutrient Cycling in Agroecosystems	6	266	44.3	2.450
Agriculture Ecosystems & Environment	4	260	65.0	4.241
Biology and Fertility of Soils	3	136	45.3	5.521
Ecological Engineering	3	129	43.0	3.512
European Journal of Soil Biology	3	185	61.7	2.285
Geoderma	3	153	51.0	4.848

Field Crops Research published 11 highly cited articles, the largest number of all journals. *Soil & Tillage Research* has the most citations and *Agriculture Ecosystems & Environment* the highest average citations per article.

Research focus on fertilizers

We used a co-occurrence network of author keywords to identify research focus and interests (Figure 6). 'Crop yield' occurred 123 times, indicating that crop yield is the prime focus of fertilizer research. Soil fertility (73), rice (69), wheat (63), economics (51), and nutrient uptake (50) are the other important themes.

We used the keywords to map the co-occurrence network and find linkages between research themes. We used VOSviewer to map seven clusters and the linkages between the keywords.

The first cluster is formed around 'crop yield' and 18 other research themes (the effects of fertilizers on crop yield, the economics of fertilizer application, nutrient uptake, soil properties, soil health, etc.).

The second cluster (18 themes) of the co-occurrence network map, surrounding 'rice', is concerned with the productivity and profitability of rice, nitrogen use efficiency, sustainability, the nutrient balance effect of climate change, water productivity, tillage, etc.

The third cluster (16 themes) focuses on the effect of the application of chemical and organic fertilizers, biofertilizers, and micronutrients on wheat and on soil quality.

The fourth cluster (16 themes) studies the environmental effects of fertilizer application, such as global warming and the emission of nitrous oxide and methane, and the management of soil organic carbon (by practising conservation agriculture and using farmyard and poultry manure, and crop residue and biomass).

The fifth cluster (12 themes) studies adsorption, biochar utilization, heavy metals contamination, and the management and disposal of hazardous materials like wastewater.

The sixth cluster studies ways to improve grain yields (using fertilizers) and nutrient use efficiency (using types of irrigation).

The seventh cluster studies the fertility and nutrient uptake of soil types.

The network map based on the bibliometric data helps to identify institutions that can produce quality research evidence especially when many organizations study a topic. Figure 7 shows the co-authorship network of the organizations that research fertilizers.

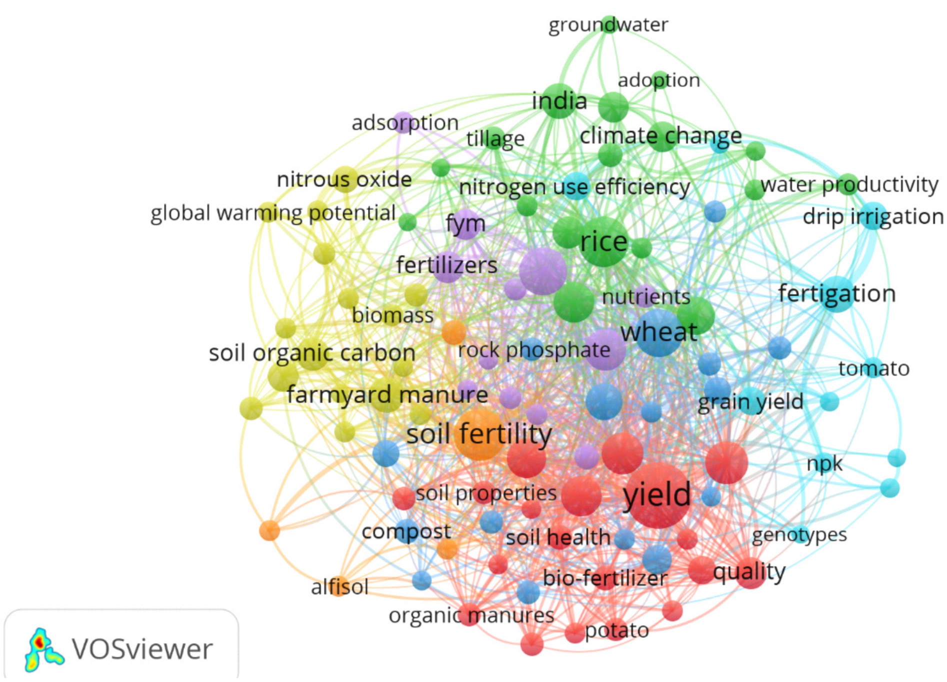

Figure 6 Co-occurrence network of the most frequently used author keywords

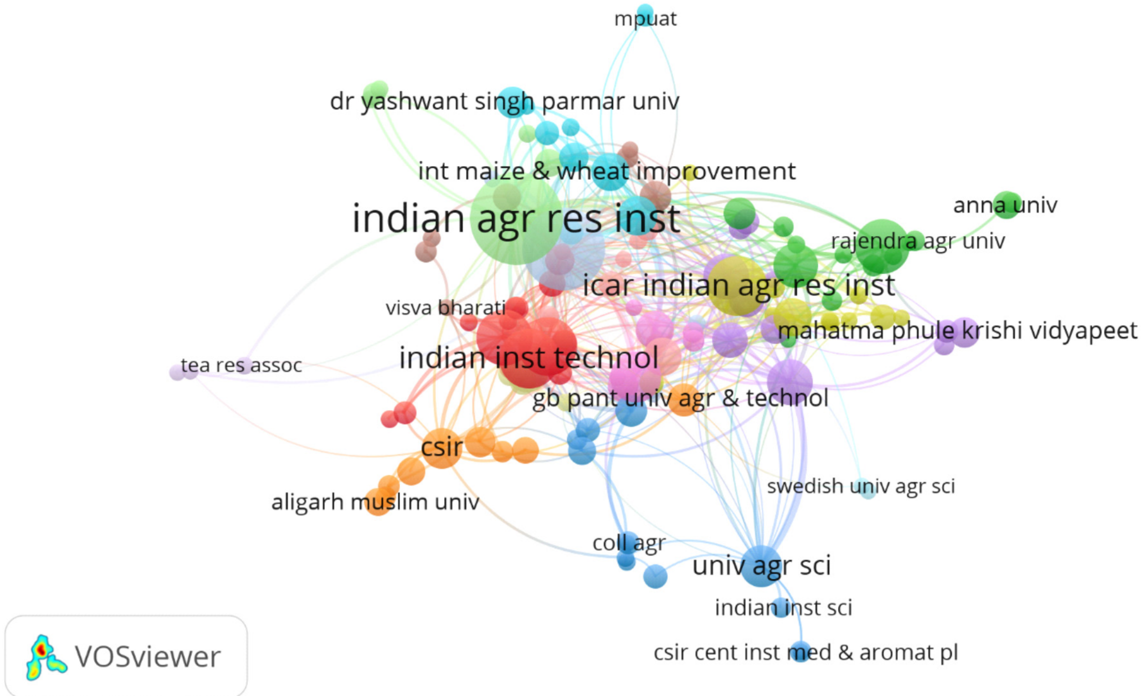

Figure 7 Co-authorship network between organizations

Over 1,400 organizations worldwide published articles on fertilizer research in India. The key international organizations are CIMMYT, Ohio State University, and International Rice Research Institute (IRRI).

The ICAR-Indian Agricultural Research Institute published 204 documents that were cited 1,696 times. The other key organizations are Punjab Agricultural University, Indian Institute of Soil Science, Central Research Institute for Dryland Agriculture, Bidhan Chandra Krishi Viswavidyalaya, and ICAR. The link strength values were the highest for ICAR-IARI (95) and Punjab Agricultural University (40), pointing towards their linkage with other organizations for fertilizer research.

The co-occurrence network of author keywords shows that researchers are focused primarily on the food security of the country, as indicated by the extensive research on rice and wheat yield. They are studying most of the challenges that we identified, such as the externalities of fertilizer application, the possibilities of reducing such negative effects through the conjunctive use of biofertilizers and organic fertilizers, nutrient use efficiency, and crop yield response to fertilizers. Research is under way to recommend location-specific fertilizers based on soil quality and their nutrient absorption capacity.

However, we detected the absence of high-quality social science research on fertilizers. Research is needed in social dimensions and ground-level evidence, as it can form the foundation for sound policies on fertilizers.

Conclusions

This paper tests the effect of key policies on fertilizer consumption in India and tracks the transition in its trends. We use national and state-level time series data for the period between 1972 and 2017. We conduct a bibliometric analysis to identify the research focus on fertilizers in India and juxtapose it with the emerging challenges.

It is widely accepted that the use of chemical fertilizers is increasing, but our study identifies that in this decade (2010–2020), the growth in the use of fertilizer nutrients has been low or negative. This is a new, country-level trend.

Importantly, the rate of growth in fertilizer use intensity across states is such that fertilizer use is moving slowly from where it has peaked to where it has a better role to play. Our analysis finds that the key policies have been effective in manoeuvring fertilizer consumption. Our bibliometric analysis finds that the research being undertaken now focuses on the challenges that we need to address soon. However, no high-quality social science research has been conducted on fertilizers from India during the study period the absence of is a caveat identified.

The findings from this study have some policy implications, especially concerning future reforms.

Policymakers targeted a reduction in the excessive use of chemical fertilizers was, but the low growth in nitrogen consumption in this decade and the negative growth in phosphorus and potash should be viewed in the context of soil nutrient balance. Care should be taken so that phosphorus and potash consumption does not fall low enough to upset the nutrient balance.

The growth in the intensity of fertilizer use in the eastern states has been high. That is heartening because the base level of fertilizer use in these states is low. Enough support should be extended to regions where the base level of fertilizer use is low so that we can reap the benefits of the higher intensity of fertilizer use.

The policies have had significant, long-term effects on fertilizer consumption because the reform measures have been well thought, framed, and implemented.

Academia considers fertilizer research important, as evidenced by the multidisciplinary nature, and growth, of high-quality literature. However, effort needs to be made to generate high-quality social science research based on ground-level data and on better stakeholder feedback to assess the impact of policies.

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References

Adhya, T, T Sapkota, and R Khurana. 2016. *AFOLU emissions*. Version 1.0 dated July 15, 2016, from GHG platform India: GHG platform India-2007-2012 National Estimates - 2016 Series. http://ghgplatform-india.org/data-and-emissions/afolu.html

Anuja, V. 2015. *Fertiliser quality in India -an assessment of fertiliser quality control, farmers' awareness and determinants of consumer choice*. Dissertation submitted to London School of Economics and Political Science, London, United Kingdom. http://www.academia.edu/download/43140221/Fertiliser_Quality_in_India.pdf

Chand, R, and S Pavithra.2015. Fertiliser use and imbalance in India. *Economic & Political Weekly* 50 (44): 98–104. https://www.epw.in/journal/2015/44/special-articles/fertiliser-use-and-imbalance-india.html

Fertilizer Association of India. 2019. *Fertilizer statistics 2018-19*. FAI, New Delhi.

Ghosh, N. 2004a. Reducing dependence on chemical fertilizers and its financial implications for farmers in India. *Ecological Economics* 49 (2): 149-162. doi:10.1016/j.ecolecon.2004.03.016

Ghosh, N. 2004b. Promoting biofertilisers in Indian agriculture. *Economic and Political Weekly* 39 (52): 5617–5625. https://www.epw.in/journal/2004/52/review-agriculture-review-issues-specials/promoting-biofertilisers-indian

Gulati, A, and P Banerjee. 2015. *Rationalising fertilizer subsidy in India: key issues and policy options.* Working Paper 307. Indian Council for Research on International Economic Relations. pp 1-9. http://icrier.org/pdf/Working_Paper_307.pdf

Hossain, M, and V P Singh. 2000. Fertilizer use in Asian agriculture: implications for sustaining food security and the environment. *Nutrient Cycling in Agroecosystems* 57 (2):155-169. doi.org/10.1023/A:1009865819925

Kanter, D R, Zhang X, and D L Mauzerall. 2015. Reducing nitrogen pollution while decreasing farmers' costs and increasing fertilizer industry profits. *Journal of Environmental Quality* 44(2): 325-335. doi: 10.2134/jeq2014.04.0173

Kapur, D. 2011. The shift to cash transfers: running better but on the wrong road? *Economic and Political Weekly* 46 (21): 80-85. https://www.epw.in/journal/2011/21/perspectives-cash-transfers-special-issues-specials/shift-cash-transfers-running

Kishore, A, K V Praveen, and D Roy. 2013. Direct cash transfer system for fertilisers. *Economic and Political Weekly* 48(52): 54-63. https://www.epw.in/journal/2013/52/review-rural-affairs-review-issues/direct-cash-transfer-system-fertilisers.html

Linden, A, and J L Adams. 2011. Applying a propensity score based weighting model to interrupted time series data: improving causal inference in programme evaluation. *Journal of Evaluation in Clinical Practice* 17(6): 1231-1238. doi: 10.1111/j.1365-2753.2010.01504.x.

Nafade V, M Nash, S Huddart S, T Pande, N Gebreselassie, C Lienhardt, and M Pai. 2018. A bibliometric analysis of tuberculosis research, 2007–2016. *PloS One* 13 (6): e0199706. doi.org/10.1371/journal.pone.0199706

Patra, S, P Mishra, S C Mahapatra, and S K Mithun. 2016. Modelling impacts of chemical fertilizer on agricultural production: a case study on Hooghly district, West Bengal, India. *Modeling Earth Systems and Environment* 2(4): 1-11. doi.org/10.1007/s40808-016-0223-6

Praveen K V. 2017. Indian fertilizer policies: revisiting the odyssey and lessons from abroad. *Current Science* 113 (7): 1246-1254. doi: 10.18520/cs/v113/i07/1246-1254

Praveen, K V. 2014. Evolution and emerging issues in fertilizer policies in India. *Economic Affairs 59* (2): 163-173. doi: 10.5958/j.0976-4666.59.2.016

Puttick, R. 2011.*Using Evidence to Improve Social Policy and Practice: Perspectives on how research and evidence can influence decision making*. NESTA. https://www.nesta.org.uk/sites/default/files/using_evidence_to_improve_social_policy_and_practice.pdf

Sharma, V P, and H Thaker H. 2011. Demand for fertilisers in India: determinants and outlook for 2020. *Indian Journal of Agricultural Economics* 66 (4): 638-661. https://ageconsearch.umn.edu/record/204787?ln=en

Van Eck, N J, and L Waltman. 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. S*cientometrics* 84(2): 523-538. doi:10.1007/s11192-009-0146-3

Zhang, X, R C Estoque, H Xie H, Y Murayama, and M Ranagalage. 2019. Bibliometric analysis of highly cited articles on ecosystem services. *PloS One* 14 (2): e0210707. doi.org/10.1371/journal.pone.0210707

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Interlink between factor and product markets: opportunity for the future of Indian agriculture

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Abstract Farm households' choice of where to sell the product (marketing channel) is endogenous to the decision of where to buy inputs (selection of an input source). Using the latest National Sample Survey Office (NSSO) Situation Assessment Survey data, and endogenous switching probit regression (ESPR), this study evaluates the impact of input market selection on the choice of (formal) product market. Compared to farm households selling to informal markets, those selling to formal product markets had significantly higher profit per unit of land. Households buying inputs from formal sources like cooperatives and government agencies were 50% more likely to choose formal channels.

Keywords Agricultural markets, endogenous switching probit regression (ESPR), agricultural supply chain, agricultural input markets, impact evaluation

JEL codes C31, Q13, Q12, Q18

Value chains strengthen forward and backward linkages and constitute an important catalyst in enhancing farmers' income (Chengappa 2018). Interactions with value chain actors across all crop types, and the complementary services they provide (inputs, credit, information, extension, etc.), help small farmers to upgrade their farming practices and improve productivity (Liverpool-Tasie et al. 2020). The forward linkages in the value chains have found considerable interest among researchers, and research can be found on the extent of price spread, technology use, poverty alleviation, sustainability, organic value chains, price transmission, and integration in value chains (Devi, Hema, and Jaikumaran 2010; Chengappa, Devika, and Manjunatha 2019; Sundaramoorthy, Mathur, and Jha 2014; Kumar et al. 2011; Kumar et al. 2012; Pandey et al. 2010). But there is little research on backward linkages (Sheldon 2017). Many researchers have documented the interlink between input, credit, and product markets (Singh and Bhogal 2015; Chatterjee and Kapur 2016; Negi et al. 2018) but, to the best of our knowledge, no study quantifies the interlinkages between factor and product markets.

Therefore, this study aims to evaluate the impact of input market selection on choice of product market (market channel). Our work is unique in several ways. First, we use data from a nationally representative survey to estimate the impact of a household's input source choice on the probability of selling to formal markets. Second, to account for the endogeneity in the choice of input and output markets, we use the endogenous switching probit regression (ESPR) model. Third, the ESPR model allows us to quantify the probability of a particular product market choice conditional on the input source, which helps us to quantify the exact relationship between a particular input and product market. Thus, this paper will be of extreme utility for researchers and policymakers who aim at developing policies to improve farmers' profitability and access to markets.

Table 1 Correlation estimates

	Input sources				Market channel		
	Own farm	Local trader	Input dealer	Cooperative/ Government	Local trader	Mandi	Input dealer
(a) Input sources							
Own farm	1.000						
Local trader	–0.282***	1.000					
Input dealer	–0.113***	–0.145***	1.000				
Cooperative/Government	–0.129***	–0.171***	–0.066***	1.000			
(b) Market channel							
Local trader	–0.022***	–0.001	0.013**	0.016***	1.000		
Mandi	–0.002	0.014**	–0.004	–0.012**	–0.665***	1.000	
Input dealer	0.014**	0.002	–0.014**	–0.002	–0.309***	–0.155***	1.000
Cooperative/Government	0.031***	–0.014**	–0.007	–0.017***	–0.286***	–0.143***	–0.067***

Note: ** and *** indicates significance at 0.05 and 0.01 level respectively
Source: Estimation based on data from NSSO (2015).

Theoretical framework

The production function approach, used to arrive at the profit and efficiency estimates of a farm, often neglects the endogeneity in the input choice of farm households (Tsionas, Kumbhakar, and Malikov 2015; Amsler, Prokhorov, and Schmidt 2016; Santín and Sicilia 2017; Petrin, Poi, and Levinsohn 2004). This study builds on the premise that a farm household's choice of value chain depends to a certain extent on its selection of input source;[1] in other words, its choice of where to buy (input) influences its choice of where to sell (product).

Agricultural markets are complex interfaces; these perform various tasks important for social reproduction and development, and these connect producers to consumers, villages to towns, and agrarian sectors to non-agrarian sectors (Jan and Harriss-White 2012). Farm households borrow from local traders, input dealers, or cooperative societies for agricultural and personal purposes, and many households offer the final produce as collateral and repay the loan in kind, i.e., the produce. Farm inputs like fertilizers are also commonly bought on a 'pay later' basis, and the final produce is pledged as payment. Farm households are believed to buy their input needs from a particular input source because it is profitable or they have no other choice, and the same can be said about the product market choice. We build on this premise—there is a significant link between factor and product market choices—and try to provide empirical evidence for this theory of interlink of choices.

The naïve methods of establishing the evidence on interlink using correlation and multivariate regression analysis is presented in Tables 1 and 2. Clearly, input and output markets are significantly associated with each other. Further, we use the endogenous switching probit regression (ESPR) model to evaluate the impact of input source selection on the choice of product markets. First, we categorize the product market into formal and informal value chains. Formal markets comprise regulated markets (mandi), cooperatives/ government agencies, and processors. Informal markets comprise local traders, input dealers, and other product markets. We determine the profitable product market among these two groups and evaluate the impact of input market selection on the choice of this profitable product market.

Endogenous switching probit regression (ESPR)

We use an ESPR model for two reasons. First, we believe that the choices of a product market and input source are endogenous, and that these choices depend on the observed and unobserved characteristics of farm

[1] Here, 'value chain' means the output destination (product market), like local traders or regulated markets, where farm households sell their produce. The terms 'value chain', 'output destination', 'market channel', and 'product market' are used interchangeably in this paper.

Table 2 Multivariate regression estimates of interlinking factor onto product markets

	Coefficient	Standard error
Dependent variable = local trader (1/0)		
Own farm (1/0)	–0.026***	0.008
Local trader (1/0)	–0.003	0.007
Input dealer (1/0)	0.025*	0.013
Cooperative/government (1/0)	0.022**	0.010
Constant term	0.572***	0.004
Regulated market (1/0)		
Own farm (1/0)	0.000	0.007
Local trader (1/0)	0.012*	0.006
Input dealer (1/0)	–0.005	0.011
Cooperative/government	–0.014*	0.008
Constant term	0.248***	0.004
Input dealer (1/0)		
Own farm (1/0)	0.009**	0.004
Local trader (1/0)	0.003	0.004
Input dealer (1/0)	–0.013**	0.007
Cooperative/government (1/0)	0.000	0.005
Constant term	0.066***	0.002
Cooperative/government (1/0)		
Own farm (1/0)	0.016***	0.004
Local trader (1/0)	–0.006*	0.003
Input dealer (1/0)	–0.006	0.006
Cooperative/government (1/0)	–0.012***	0.005
Constant term	0.058***	0.002

Note: *, ** and *** indicates significance at 0.1, 0.05 and 0.01 level respectively

Source: Estimation based on data from NSSO (2015).

households. Second, we have binary dependent variables in both the selection and outcome equations (factor and product market choices are binary).

The problem at hand is estimating the impact of an input source selection on formal product market participation. For illustration we will look at the impact of buying inputs from local traders (selection) on formal product market choice (outcome). The treatment here is buying from an input source (local traders in the illustration) and the outcome is the probability of selling to a formal value chain.

Let L_i^* be the propensity of a household to buy from local traders in a linearized form

$$L_i^* = \delta Z_i + \mu_i \quad \ldots(1)$$

where i is the HH, δ is the parameter vector, Z_i is a vector of observable household characteristics like household characteristics, socioeconomic characteristics, and access to information, training, and social safety nets; μ_i is the error term.

A household's observed input-buying status from a local trader L_i can be written as

$$L_i = 1\ (L_i^* > 0) = 1\ (\delta Z_i + \mu_i > 0) \quad \ldots(2)$$

where 1(.) is an indicator function.

Further, a household's latent choice of a formal product market can be expressed as

$$F_{ij} = \beta_j X_i + \varepsilon_{ij}, j = 0, 1 \quad \ldots(3)$$

where X_i are the household characteristics, socioeconomic characteristics, and access to information, training, and social safety nets. β_j is the regime specific parameter vector and ε_{ij} is the error term; j denotes the two regimes (buy/do not buy from local trader). Now, let PM_{ij} denote the households observed choice of a product market, such that:

$$PM_{ij} = 1\ [F_{ij} \geq 0] = 1\ [\beta_j X_i + \varepsilon_{ij} \geq 0], j = 0, 1 \quad \ldots(4)$$

In ESPR we assume that the three error terms μ_i, ε_{10} and ε_{01} in equation (2), (3) and (4) are jointly normally distributed with zero mean and correlation matrix

$$\begin{bmatrix} 1 & \rho_{\mu 0} & \rho_{\mu 1} \\ & 1 & \rho_{01} \\ & & 1 \end{bmatrix}$$

Here, $\rho_{\mu 0}$ is the correlation between μ and ε_0; similarly, $\rho_{\mu 1}$ is the correlation between μ and ε_1 and ρ_{01} is the correlation between and . As and cannot be observed together, the joint distribution of $(\varepsilon_0 \varepsilon_1)$ is not identified. Thus, ρ_{01} cannot be estimated.

The log-likelihood function for the system of equations (2–4) was estimated using the maximum likelihood (ML) estimation to account for endogeneity in factor and product market choices. We used the 'switch_probit' Stata routine to estimate the ESPR model (Lokshin and Sajaia 2011). Switching models can also be fitted using other ML estimations or by estimating one branch at a time with Stata routines like 'biprobit' or 'heckprob'. However, using these estimation methods to yield consistent standard errors require cumbersome adjustments, and these methods are inefficient (Lokshin and Sajaia 2011).[2]

The log-likelihood functions can be used to generate counterfactual scenarios for households in different regimes of buying from local traders and formal market participation (Lokshin and Glinskaya 2009; Lokshin and Sajaia 2011). These can then be used to calculate the impact of selecting local traders on formal product market choice using the methodological framework provided by Aakvik, Heckman, and Vytlacil (2000; 2005). The impact of choosing a local trader on a household with observable characteristics if it buys from a local trader can be interpreted as the treatment effect on the treated (TT):

$$TT(x) = \Pr[PM_1 = 1|L = 1, X = x] - \Pr[PM_2 = 1|L = 1, X = x] \quad \ldots(5)$$

TT is the difference between the predicted probability of formal market participation of a household that had bought inputs from a local trader and the probability of formal market participation had the household not decided to buy from local traders. The average treatment effect on the treated (ATT) is obtained by simply averaging (5) over the total number of households buying from local traders (treated).

The impact of buying inputs from a local trader on the probability of a household's formal product market participation randomly drawn from the population of households with characteristics can be called the treatment effect (TE):

$$TE(x) = \Pr[PM - 1|\ X = x] - \Pr[PM - 0 \mid X = x] = F[\beta_1 X] - F[\beta_0 X] \quad \ldots(6)$$

The average treatment effect (ATE) is obtained by simply averaging (6) over the total number of households drawn from the population. The impact of treatment on a household with observable characteristics x if it does not buy from a local trader can be interpreted as the treatment effect on the untreated (TU):

$$TU(x) = \Pr[PM_1 = 1|L = 0, X = x] - \Pr[PM_2 = 1|L = 0, X = x] \quad \ldots(7)$$

TU is the difference between the predicted probability of formal market participation of a household that had not bought inputs from a local trader and the probability of formal market participation had the household decided to buy from local traders. The ATE on the untreated (ATU) is obtained by averaging (7) over the total number of households not buying from local traders (untreated).

Next, we calculate the marginal treatment effect (MTE), which accounts for the unobserved heterogeneity in the sample (Lokshin and Glinskaya 2009); the MTE is used when the impact is believed to vary within the sample population in correlation with the unobservable characteristics (Brave and Walstrum 2014). The MTE identifies the effect of treatment (input source selection) on those induced to change treatment states (selling to formal/informal product markets) by the intervention (input source) (Aakvik, Heckman, and Vytlacil 2005). Therefore, the MTE is the effect of the input source on inducing changes in the product market decision of households because of the particular input source. The MTE can be written as:

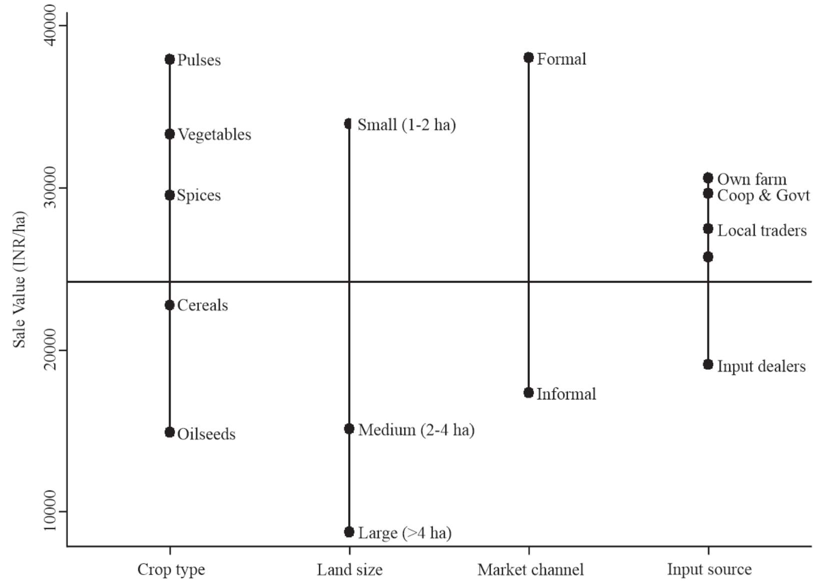
$$MTE(x,\mu) = \Pr[PM_1 \mid X = x, \mu = \bar{\mu}] - \Pr[PM_0 \mid X = x, \mu = \bar{\mu}] \quad \ldots(8)$$

The ESPR model described in this paper is identified through nonlinearities in the functional form. It is robust in terms of identification and there is no need for exclusion restrictions (in these kinds of recursive multiple equation probit regressions with endogenous binary regressors) if there is sufficient variation in the exogenous variables (Lokshin and Sajaia 2011; Wilde 2000).

Data

The National Sample Survey Organisation (NSSO) conducts the Situation Assessment Survey of Agricultural Households and collects observational data, which is used in this study (NSSO 2015). The data was accessed from the ICSSR Data Service: Social Science Data Repository (http://www.icssrdataservice.in/datarepository/index.php/catalog/104). The survey used stratified multistage random sampling with census villages as first stage units and households as last stage units. The data on the value chain—input source and product disposition—of Visit 1 was used for our work. The NSSO collected this data (Visit 1) using face-to-face interviews, which were conducted from 1 January 2013 to 31 July 2013.

[2] For a discussion of the advantages of the ESPR over instrumental variable and bivariate probit regression see Lokshin and Glinskaya (2009).



Source: Estimation based on data from (NSSO 2015)

Note: Kruskal-Wallis equality-of-populations rank test statistics showed that the sale value of product (per ha) differed significantly among crop type, land size, market channel, and input source categories at 1% level

Figure 1 Commodity sale value across crop grown, landholding, market channel, and input source

Farm income and profits

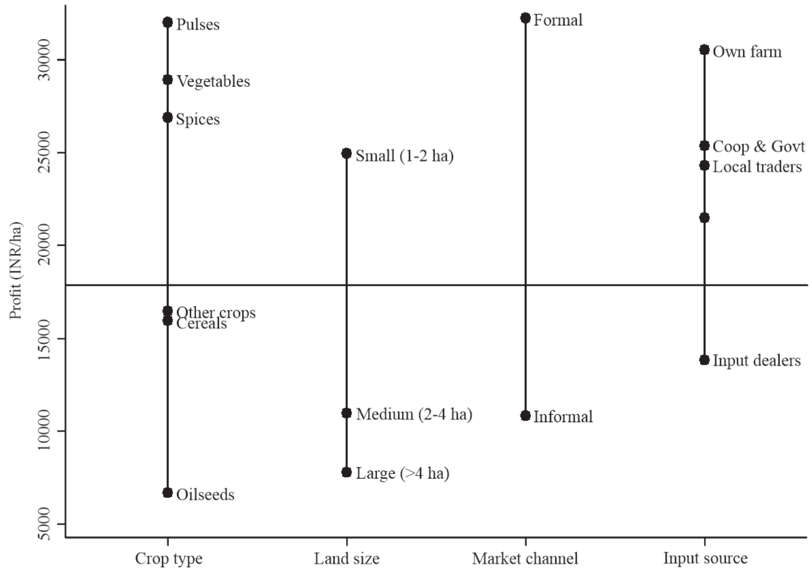
Figure 1 presents the farm income (sale value of product) by crop type, farm size, product destination, and input source. Farm income varied significantly within each group (tested using Kruskal-Wallis equality-of-populations rank test). Farm income was higher among households growing pulses, followed by those growing vegetables, spices, cereals, and other crops and oilseeds. The dispersion from the mean was higher for pulses (16178) than for high-value crops such as vegetables (2555) and spices (4115). 'Other' crops include sugar, fibre, fodder, dye, tobacco, and medicinal, aromatic, and plantation crops. Farm income per hectare was inversely related to farm size; the income was higher for small landholdings than medium and for medium landholdings than large. This finding is in line with other studies (Sen 1962; Bardhan 1973; Deolalikar 1981; Deininger et al. 2015; Sheng, Ding, and Huang 2019).

The income was higher for farmers selling to the formal market channel (regulated markets or mandis, processors, cooperatives and government agencies) than for households selling to informal value chains (local traders, input dealers, and others). Further, farm households that used inputs from their own farm or bought inputs from cooperatives and government sources earned a higher income than households that bought inputs from local traders and input dealers. The pattern of profits was similar to that of farm income across crop type, farm size, product destination, and input source (Figure 2).

Profits were highest among households that used inputs from own farm, followed by households buying from cooperatives, local traders, and input dealers. As the main aim of the study is to know how input market selection affects choice of formal markets, we further test whether the profits differ significantly across formal and informal value chains. The Kolmogorov–Smirnov test revealed that the distribution of formal and informal value chains were significantly different (Figure 3). This justifies the use of formal value chain choice as the dependent variable in the outcome equation of the ESPR.

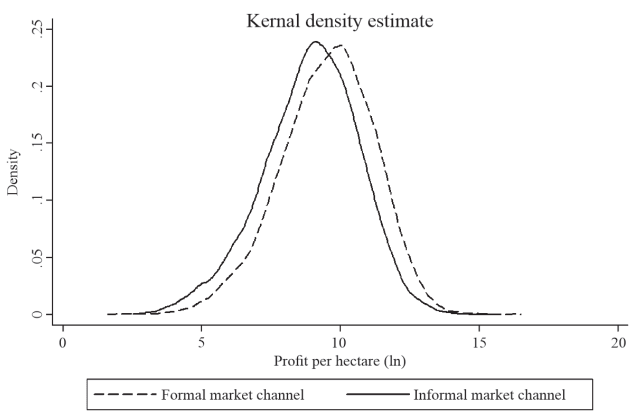
Balance test

The differences between some of the observable characteristics of households selling to informal and formal product markets are calculated to test whether these characteristics in both groups were similar or different (Table 3). The results clearly indicate that the



Source: Estimation based on data from NSSO (2015)
Note: Profit = sale value " input costs
Kruskal-Wallis equality-of-populations rank test statistics showed that the profit per hectare differed significantly among crop type, land size, market channel, and input source categories at 1% level

Figure 2 Farm profit across crop grown, landholding, value chain, and input source



Source: Estimation based on data from NSSO (2015)
Note: Kolmogorov–Smirnov test statistics showed that the distribution for formal and informal market channels differ at 1% level

Figure 3 Cumulative distributions of profits across formal and informal value chain

households selling to informal markets were systematically different from households selling to formal markets. For instance, the proportion of Scheduled Tribes (STs) and Other Backward Classes (OBC) was significantly larger in households selling to informal markets than in households selling to formal markets. Households selling to informal markets were younger, and they had smaller landholdings; they had lower value of product and net return, and less of outstanding loans. Therefore, the results indicated, farm households that had younger members and larger landholdings earned a higher income and profit and enjoyed greater liquidity, and they sold their produce at formal markets.

Results and discussion

The logit estimates of the determinants of the choice of value chain are presented in Table 4. The coefficient of quantity sold was positive and significant. As the quantity sold increases by 1% the chance of selling in formal markets increases by around 5%. Farmers who are able to produce larger quantities are more likely to choose formal marketing channels.

Choice of value chain

Households might find the price paid by informal markets low; they might clear the dues (cash or input credit) at informal markets and sell the rest of the produce at formal markets. Households might also find that the prices at formal markets offset their transaction cost (transporting the produce to the destination). Households growing oilseeds were 14% more likely

Table 3 Mean difference between key indicators of households using informal and formal value chain

Variables	Informal		Formal		Mean difference
	Frequency	Mean	Frequency	Mean	
Schedule Caste (1/0)	20167	0.13	9897	0.14	–0.01***
Scheduled Tribe (1/0)	20167	0.22	9897	0.19	0.04***
Other Backward Caste (1/0)	20167	0.38	9897	0.36	0.02***
General (1/0)	20167	0.27	9897	0.31	–0.04***
MGNREGA (1/0)	20155	0.46	9891	0.45	0.01
PDS (1/0)	20155	0.87	9891	0.88	–0.01***
Land owned (ha)	19842	1.00	9717	1.05	–0.05**
Land leased in (ha)	20167	0.09	9897	0.11	–0.01
Land leased out (ha)	20167	0.03	9897	0.04	–0.01**
Land possessed (ha)	20150	1.10	9886	1.14	–0.04*
Input expenses (INR/ha)	20068	8283	9802	7635.35	647.98
Total value (INR/ha)	19970	45000	9768	54000	–8800***
Net return (INR/ha)	19871	37000	9673	46000	–9300***
Loan outstanding (INR)	20167	72000	9897	90000	–17000***
Family size (number)	20167	5.47	9897	5.56	–0.08**
Age (years)	20167	28.77	9896	28.78	–0.01
Production from irrigated land (ha)	14024	0.59	7019	0.58	0.01
Production from unirrigated land (ha)	6667	0.32	3053	0.36	–0.04

Source: Estimation based on data from (NSSO 2015)
Note: *, ** and *** indicates significance at 0.1, 0.05 and 0.01 level, respectively

to sell at formal markets and those growing fruits were 15% more likely, and households of higher social groups (General) were 4% more likely to sell at formal markets.

Factors such as age group, family size, or education level did not influence farm households' choice of value chain. Households borrowing from professional moneylenders were more likely to sell at formal markets, possibly because they need the higher prices to repay their high-interest loans, or because moneylenders, who are a part of the mandis, have an information advantage and they pass it on to needy farm households.

Finally, households buying inputs from local traders, cooperatives, and government agencies are less likely to sell at formal markets. The opposite is true for households buying inputs from input dealers. They are 9.3% more likely to sell at formal markets relative to households using inputs of their own farm. The logit estimates (Table 4) point to the partial correlation between variables and not the causation.

Impact of input source selection on choice of value chain

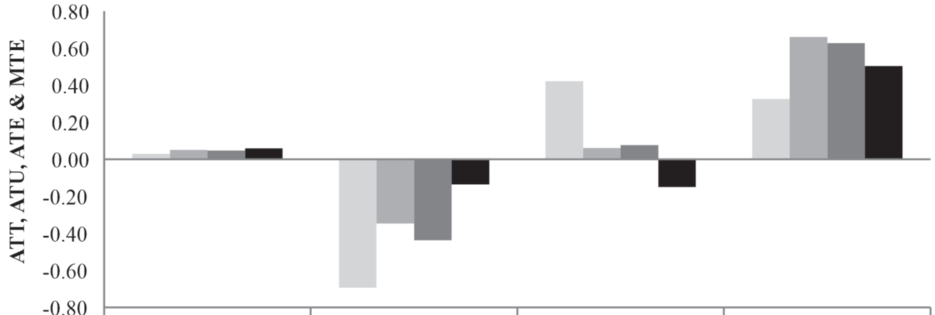
The impact estimates are computed from the ESPR model (Figure 4). Households using inputs from their own farm were 3%–6% more likely to sell through formal value chains relative to had they bought inputs from any other source. The impact estimates of households buying inputs from the local traders ranged from "14% MTE to "69% ATT; these households were 14%–69% less likely to sell through the formal value chains relative to a scenario that they had not bought from the local traders.

Households buying from input dealers had a higher ATT of 42%, implying that they were 42% more likely to sell through formal product markets relative to a scenario that they had not sold to the formal product markets. The MTE, which accounts for the endogeneity in the sample, was negative for households buying from the input dealers; input dealers were less likely to induce changes in the product market choices of households from informal to formal. Considering the

Table 4 Determinants of choice of value chain

	Formal (1/0)	Robust Std. Err.	Marginal effects dy/dx	Std. Err.
Quantity sold (ln)	0.201***	0.019	0.045***	0.004
Type of crops grown				
Cereals (1/0)	-0.040	0.071	-0.009	0.016
Pulses (1/0)	0.114	0.273	0.026	0.063
Vegetables (1/0)	0.012	0.117	0.003	0.026
Oilseeds (1/0)	0.607**	0.285	0.144**	0.071
Fruits (1/0)	0.634***	0.181	0.151***	0.045
Spices (1/0)	-0.160	0.216	-0.034	0.045
MSP awareness (1/0)	-0.004	0.100	-0.001	0.022
Land size (base: Marginal)				
Small (1–2 ha)(1/0)	0.033	0.073	0.007	0.016
Medium (2–4 ha) (1/0)	-0.132*	0.079	-0.029	0.017
Large (>4 ha)(1/0)	0.094	0.116	0.021	0.026
Technical advice (1/0)	0.117	0.107	0.026	0.024
Source of inputs (Base: Own)				
Local trader (1/0)	-0.157**	0.078	-0.034**	0.017
Input dealer (1/0)	0.398***	0.141	0.093***	0.034
Cooperative & Government agency (1/0)	-0.262**	0.105	-0.056***	0.021
Social group/Caste (Base: Scheduled Tribe)				
Scheduled Caste (1/0)	-0.003	0.106	-0.001	0.024
Other Backward Class (1/0)	0.032	0.085	0.007	0.019
General (1/0)	0.183**	0.088	0.041**	0.020
Education level (Base: Illiterate)				
Literate without formal schooling (1/0)	-0.316	0.336	-0.066	0.065
Literate but below primary (1/0)	0.096	0.093	0.022	0.021
Primary (1/0)	0.097	0.123	0.022	0.028
Middle (1/0)	0.085	0.097	0.019	0.022
Secondary (1/0)	0.098	0.152	0.022	0.034
Graduate and above (1/0)	0.024	0.151	0.005	0.034
Source of credit				
Cooperative and government (1/0)	0.035	0.096	0.008	0.021
Bank (1/0)	0.162	0.121	0.036	0.028
Agricultural/ Professional moneylender (1/0)	0.326***	0.100	0.075***	0.024
Shopkeeper/Trader (1/0)	0.107	0.132	0.024	0.030
Friends and relatives (1/0)	-0.020	0.126	-0.004	0.028
Age (years)	0.001	0.002	0.000	0.000
Family size (numbers)	-0.001	0.015	0.000	0.003
Constant	-2.213***	0.194		

Note: *, ** and *** indicates significance at 0.1, 0.05 and 0.01 level respectively



	Own farm	Local trader	Input dealer	Cooperative & Government
ATT	0.03	-0.69	0.42	0.33
ATU	0.05	-0.35	0.06	0.66
ATE	0.05	-0.44	0.08	0.63
MTE	0.06	-0.14	-0.15	0.50

Note: All the estimates were significant at 1% level

Figure 4 ESPR estimates of impact on formal value chain selection

interaction of unobserved characteristics that might drive formal market participation (MTE), the selection of input dealers makes the households 15% less likely to sell through the formal marketing channels.

Households buying inputs from cooperatives and government agencies had positive coefficient values across all impact estimates. Households that buy from cooperatives and government agencies were 33% more probable to choose formal product markets than if they had not bought from cooperatives and government agencies. If those households that do not buy from cooperatives and government agencies had bought inputs from them (ATU), they would have 66% more chance of selling their produce profitably in the formal product markets.

Overall, the ATE of buying from cooperatives and government agencies was 63%, implying again a higher chance of selling the produce profitably. Accounting for the effect of unobservable characteristics, the effect of buying from cooperatives and government agencies was 0.50 (MTE). Therefore, we can conclude that households are more likely to be profitable if they buy inputs from cooperatives and government agencies than other sources.

Dominance of local traders: an opportunity

We further evaluate the effect of choice of input source on formal product market choice by plotting the ATE across different types of crops grown and land holding. The farm households buying inputs from local traders and dealers are more likely to sell at informal product markets (local private traders and input dealers). Oilseeds and pulses growers who buy inputs from local traders are around 50% more (less) likely to sell their produce to informal (formal) product markets (Figure 5). The treatment effect is near homogenous across the landholding sizes (Figure 6). The households that buy inputs from informal sources are more likely to sell at informal markets. Just by the virtue of its scale—around 44% of farm households buy from local private players, 63% sell to them, and around 25% borrow from them (Appendix Figures 1, 2 and 3)—this nexus between

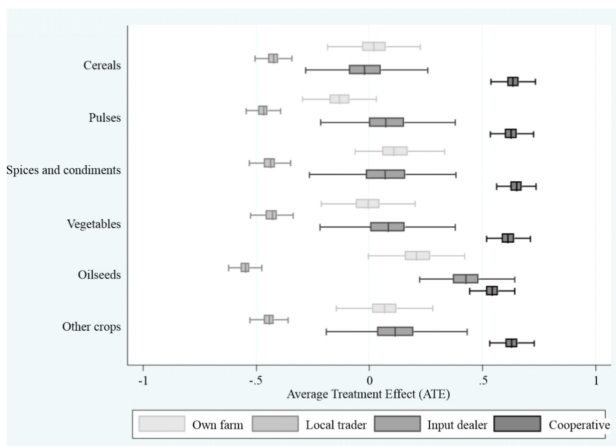


Figure 5 Average treatment effect (ATE) across type of crops grown

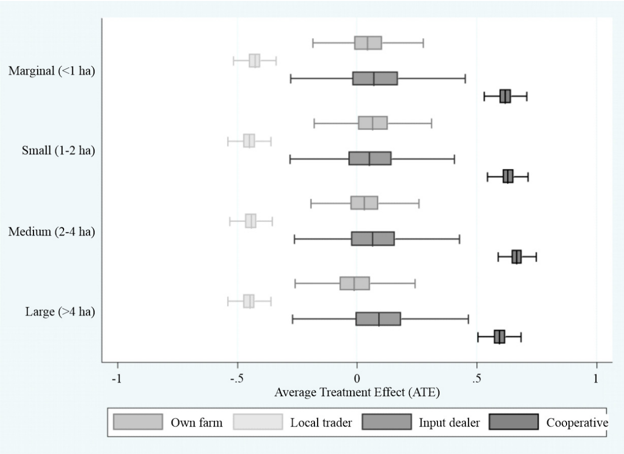


Figure 6 Average treatment effects (ATE) by landholding

informal traders is a huge concern for the agrarian economy.

But this nexus also presents an opportunity: these networks can be used to pass on to farmers new information on inputs, prices, products, technology, and better farm practices and, therefore, benefit farm households. The dominance of informal traders be converted into a new, efficient agricultural marketing system that profits farmers, and this study strongly recommends it. The reliability of these local players can be increased by the interventions of modern value chains like business-to-consumer (B2C) (direct marketing from producer to consumer) and contract farming.

Under contract farming, farmers and private players (large retailers, aggregators, agribusiness firms, etc.) contract to grow crops at a price they mutually agree to; contract farming has improved efficiency, productivity, and farmer income and lowered transaction costs (Kalamkar 2012; Barrett et al. 2012; Birthal, Jha, and Singh 2007; Kumar et al. 2019; Swain 2016; Chengappa 2018). Some challenges—like input pricing, delay in input delivery, and upfront investment— remain, but these are manageable. The Farmers (Empowerment and Protection) Agreement on Price Assurance and Farm Services Act, 2020 (Contract Farming Act) promotes legal contract farming. The Farmers' Produce Trade and Commerce (Promotion and Facilitation) Act, 2020, promotes farmers' freedom of choice in selecting market channels. Together, these Acts could catalyse the process of breaking the dominance of local traders and making them reliable.

A few concerns remain, however, in areas where these interlinkages provide farmers other services, like farm and non-farm credit. Financial institutions should also be a part of this change and supplement the reforms. To accelerate agricultural growth and development, therefore, the need of the hour is a coordinated effort by agribusiness firms, farmer producer companies, corporate investors, entrepreneurs, and financial institutions.

Conclusions

The agricultural market system is undergoing a structural change, and it is important to identify the extent of interconnection between the backward and forward linkages of the value chains and harness the interlinks to the welfare of agricultural households and rural development. Keeping this in mind we aimed at measuring the interlink between agricultural input and output markets.

The study found that households selling their product through formal markets (regulated markets, cooperatives, government agencies, and processors) were realizing significantly higher profits than those selling through informal markets. An attempt was made to estimate the impact of choosing an input source on selling through these profitable formal product markets. It was observed that households buying their inputs from cooperative or government agencies were highly likely to use formal product markets and, conversely, households meeting their farm input needs from local traders were extremely unlikely to sell through formal product markets. A sizeable sample of the households were dependent on these dominant local traders, and the weakness of this informal market is definitely a major concern for the development of agricultural households but, this study strongly holds, this concern can be turned into an opportunity.

The existing links in these massive networks–covering the input, credit, and market requirements of households—can be used to disseminate vital information regarding market intelligence, innovations, best farming practices, crops, inputs, new technologies, weather, and Government schemes. Cooperative and government agencies working in the input markets should be strengthened and encouraged, as these significantly impact the formal market participation of households.

The reliability of these local players can be increased by the interventions of modern value chains like business-to-consumer (B2C) (direct marketing from producer to consumer) and contract farming. The recent Acts and the amendments to the Agricultural Produce Market Committee and Essential Commodities Act by the union government, is a welcome policy response in this direction.

References

Aakvik, A, J J Heckman, and E J Vytlacil. 2000. Treatment effect for discrete outcomes when responses to treatment vary among observationally identical persons: an application to Norwegian vocational rehabilitation programs, Vol 7, Technical working paper series No 262. nber.org/papers/t0262.pdf.

Aakvik, A, J J Heckman, and E J Vytlacil. 2005. Estimating treatment effects for discrete outcomes when responses to treatment vary: an application to Norwegian vocational rehabilitation programs. *Journal of Econometrics* 125: 15–51. doi.org/10.1016/j.jeconom.2004.04.002.

Amsler, C, A Prokhorov, and P Schmidt. 2016. Endogeneity in stochastic frontier models. *Journal of Econometrics* 190 (2): 280–88. doi.org/10.1016/j.jeconom.2015.06.013

Bardhan, P K. 1973. Size, productivity, and returns to scale: an analysis of farm-level data in Indian agriculture. *Journal of Political Economy* 81 (6): 1370–86. jstor.org/stable/1830745

Barrett, C B, M E Bachke, M F Bellemare, H C Michelson, S Narayanan, and T F Walker. 2012. Smallholder participation in contract farming: comparative evidence from five countries. *World Development* 40 (4): 715–30. doi.org/10.1016/j.worlddev.2011.09.006

Birthal, P S, A K Jha, and H Singh. 2007. Linking farmers to markets for high-value agricultural commodities. *Agricultural Economics Research Review* 20: 425–39. dairyknowledge.in/sites/default/files/linking_farmers_to_markets_for_high_value_agricultural_commodities.pdf

Brave, S, and T Walstrum. 2014. Estimating marginal treatment effects using parametric and semiparametric methods. *The Stata Journal: Promoting Communications on Statistics and Stata* 14 (1): 191–217. doi.org/10.1177/1536867x1401400113

Chatterjee, S, and D Kapur. 2016. Understanding price variation in agricultural commodities in India: MSP, government procurement, and agriculture markets. In India policy forum, July 12-13, National Council of Applied Economic Research, New Delhi. ncaer.org/events/ipf-2016/IPF-2016-Paper-Chatterjee-Kapur.pdf

Chengappa, P G. 2018. Development of agriculture value chains as a strategy for enhancing farmers ' income. *Agricultural Economics Research Review* 31 (1): 1–12. doi.org/10.5958/0974-0279.2018.00001.0

Chengappa, P G, C M Devika, and A V Manjunatha. 2019. Coffee value chains in India: exploring sustainability oriented markets. *Agricultural Economics Research Review* 32 (1): 91–104. doi.org/10.5958/0974-0279.2019.00008.9

Deininger, K, S Jin, Y Liu, and S Singh. 2015. Labor market performance and the farm size-productivity relationship in rural India. In 2015 conference, August 9-14, 2015, Milan, Italy. ideas.repec.org/p/ags/iaae15/212720.html%0Ahttp://files/529/212720.html

Deolalikar, A B. 1981. The inverse relationship between productivity and farm size: a test using regional data from India. *American Journal of Agricultural Economics* 63 (2): 275-79. doi.org/10.2307/1239565

Devi, P I, M Hema, and U Jaikumaran. 2010. Value chain in poverty alleviation - a model for institutional initiatives for organizing and capacity building of farm work force. *Agricultural Economics Research Review* 23: 523–26. search.ebscohost.com/login.aspx?direct=true&db=bth&AN=58657019&site=ehost-live

Jan, M A, and B Harriss-white. 2012. The three roles of agricultural markets: a review of ideas about agricultural commodity markets in India. *Economic and Political Weekly* 47 (52): 39–52. jstor.org/stable/41720550

Kalamkar, S S. 2012. Inputs and services delivery system under contract farming: a case of broiler farming. *Agricultural Economics Research Review* 25: 2012–2515. ageconsearch.umn.edu/bitstream/136383/2/17-SS-Kalamkar.pdf

Kumar, A, D Roy, P K Joshi, G Tripathi, and R P Adhikari. 2019. Impact of contract farming of paddy seed on smallholder farm profits: evidence from Nepal. *Agricultural Economics Research Review* 32 (1): 25. doi.org/10.5958/0974-0279.2019.00003.x

Kumar, A, H Singh, S Kumar, and S Mittal. 2011. Value chains of agricultural commodities and their role in food security and poverty alleviation – a synthesis. *Agricultural Economics Research Review* 24 (June): 169–81. https://ageconsearch.umn.edu/record/109516/files/18-Anjani-Kumar.pdf

Kumar, R, K Alam, V V Krishna, and K Srinivas. 2012. Value chain analysis of maize seed delivery system in public and private sectors in Bihar. *Agricultural Economics Research Review* 25: 387–98. DOI: 10.22004/ag.econ.136392

Liverpool-Tasie, L S O, A Wineman, S Young, J Tambo, C Vargas, T Reardon, G S Adjognon, et al. 2020. A scoping review of market links between value chain actors and small-scale producers in developing regions. *Nature Sustainability* 3 (10): 799–808. doi.org/10.1038/s41893-020-00621-2

Lokshin, M, and E Glinskaya. 2009. The effect of male migration on employment patterns of women in Nepal. *World Bank Economic Review* 23 (3): 481–507. doi.org/10.1093/wber/lhp011

Lokshin, M, and Z Sajaia. 2011. Impact of interventions on discrete outcomes: maximum likelihood estimation of the binary choice models with binary endogenous regressors. *Stata Journal* 11 (3): 368–85. doi.org/10.1177/1536867x1101100303

Negi, D S, P S Birthal, D Roy, and M T Khan. 2018. Farmers' choice of market channels and producer prices in india: role of transportation and communication networks. *Food Policy* 81 (October): 106–21. doi.org/10.1016/j.foodpol.2018.10.008

NSSO. 2015. Situation assessment survey of agricultural households: NSS 70th round, schedule 33, January - December 2013 (visit 1). ICSSR data service: social science data repository, 2015. icssrdataservice.in/datarepository/index.php/catalog/104/data_dictionary

Pandey, T, N Krishna, V Vickers, A Menezes, and M Raghavendra. 2010. Innovative payment solutions in agricultural value chain as a means for greater financial inclusion. *Agricultural Economics Research Review* 23: 527–34. https://www.farm-d.org/app/uploads/2019/05/17-Tushar-Pandey.pdf

Petrin, A, B P Poi, and J Levinsohn. 2004. Production function estimation in stata using inputs to control for unobservables. *The Stata Journal: Promoting Communications on Statistics and Stata* 4 (2): 113–23. doi.org/10.1177/1536867x0400400202

Santín, D, and G Sicilia. 2017. Dealing with endogeneity in data envelopment analysis applications. *Expert Systems with Applications* 68: 173–84. doi.org/10.1016/j.eswa.2016.10.002

Sen, A. 1962. An aspect of Indian agriculture. *Economic Weekly* 14 (4–6): 243–46. epw.in/journal/1962/4-5-6/agricultural-front-commentary/aspect-indian-agriculture.html

Sheldon, I M. 2017. The competitiveness of agricultural product and input markets: a review and synthesis of recent research. *Journal of Agricultural and Applied Economics* 49 (1): 1–44. doi.org/10.1017/aae.2016.29

Sheng, Y, J Ding, and J Huang. 2019. The relationship between farm size and productivity in agriculture: evidence from maize production in northern China. *American Journal of Agricultural Economics* 101 (3): 790–806. doi.org/10.1093/ajae/aay104.

Singh, S, and S Bhogal. 2015. Commission agent system. *Economic and Political Weekly* 50 (45): 56–62. epw.in/journal/2015/45/special-articles/commission-agent-system.html

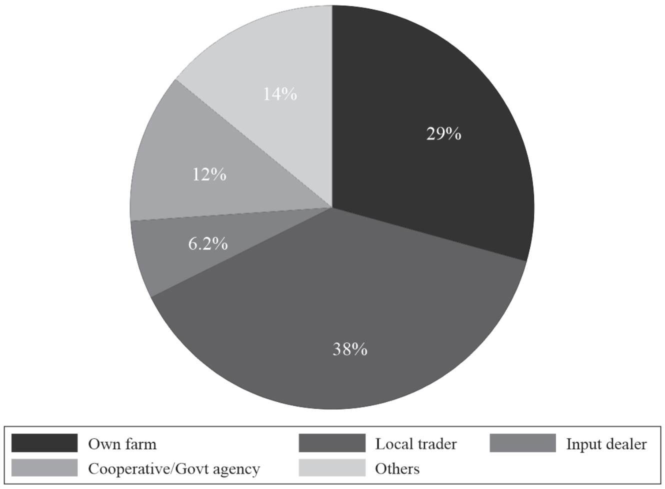
Sundaramoorthy, C, V C Mathur, and G K Jha. 2014. Price transmission along the cotton value chain. *Agricultural Economics Research Review* 27 (2): 177–86. doi.org/10.5958/0974-0279.2014.00022.6

Swain, B B. 2016. Does technological linkage in contract farming increase farm productivity and efficiency? the case of hybrid paddy seed cultivation in undivided Andhra Pradesh. *Agricultural Economics Research Review* 29 (2): 211. doi.org/10.5958/0974-0279.2016.00049.5

Tsionas, E G, S C Kumbhakar, and E Malikov. 2015. Estimation of input distance functions: a system approach. *American Journal of Agricultural Economics* 97 (5): 1478–93. doi.org/10.1093/ajae/aav012

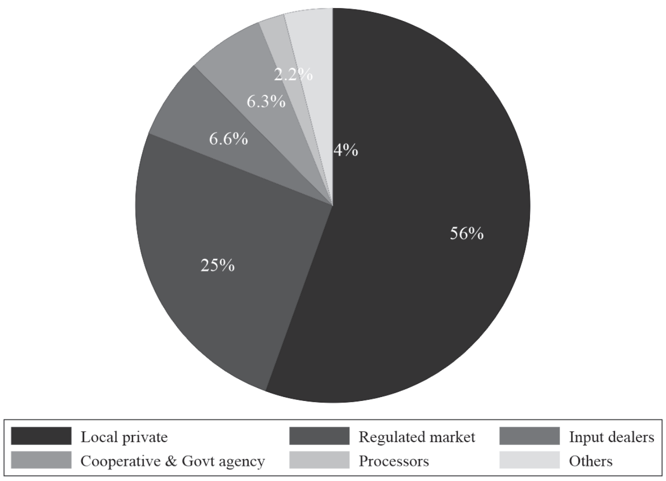
Wilde, J. 2000. Identification of multiple equation probit models with endogenous dummy regressors. *Economics Letters* 69 (3): 309–12. doi.org/10.1016/S0165-1765(00)00320-7.

Appendix



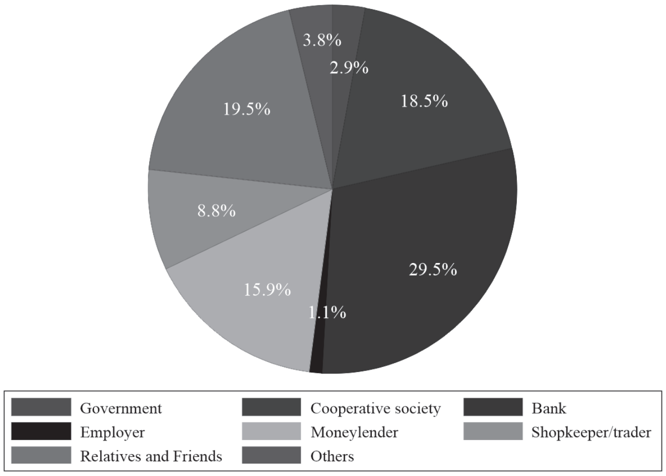
Source: Estimation based on data from NSSO (2015)

Figure 1 Distribution of households across input agencies



Source: Estimation based on data from (NSSO 2015)

Figure 2 Distribution of households across product destination



Source: Estimation based on data from NSSO (2015)

Figure 3 Distribution of households across source of borrowing

Table 1 Distribution matrix of farm households' input and output market choice (%)

Market channel/input source	Own farm	Local trader	Input dealer	Coop & Govt	Others	Total
Distribution of households' input sources within different market channels						
Local private	28.70	40.86	5.45	12.40	12.56	100
Regulated market	28.52	37.22	7.73	10.35	16.33	100
Input dealers	31.74	39.10	6.60	12.83	9.72	100
Cooperative & Govt agency	33.92	30.69	7.90	9.16	18.33	100
Processors	32.57	20.23	9.82	8.52	28.87	100
Others	30.89	31.52	2.53	21.93	13.12	100
Total	29.33	38.43	6.26	11.98	14.11	100
Distribution of households' market channel choice within different input sources						
Local private	53.65	58.29	47.70	56.77	48.80	54.83
Regulated market	25.33	25.23	32.16	22.51	30.14	26.05
Input dealers	7.31	6.87	7.12	7.24	4.65	6.76
Cooperative & Govt agency	7.12	4.92	7.77	4.71	8.00	6.16
Processors	2.60	1.23	3.67	1.67	4.80	2.34
Others	4.09	3.18	1.57	7.10	3.61	3.88
Total	100	100	100	100	100	100

Note: Percentages were calculated based on the weighted frequency distribution across combination of input and output sources
Source: Estimation based on data from (NSSO 2015)

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Assessment of spatial price linkages in the major potato-assembling markets in India

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Abstract The study analyses the spatial linkages of Agra, Hooghly, Firozpur, Pune, and Delhi potato markets. The Granger causality technique is used to identify the causal relationship between the price series in the potato markets, and the Delhi market is found to be the price leader. The shocks arising in the Delhi market are transmitted to all the other markets. To identify the price triggers in the major price-influencing markets, the variance decomposition technique is applied, which reveals that the forecast error variance in Delhi is explained by the variable itself both in the short and long run.

Keywords Cointegration, Granger causality, impulse response, instability, variance decomposition

JEL codes C21, C23, C32, Q13

The topography in India and its agroclimatic conditions are suitable for horticultural crops, and the cultivation of these crops has the potential of providing small and marginal farmers an ideal source of livelihood. India has come a long way in horticulture; the area under horticultural crops grew 2.6% over the last few years and production increased 4.8% annually. The production of horticulture crops in 2017–18 was 311.71 million tons from an area of 25.43 million hectares. At the moment, India is the second-largest producer of fruits and vegetables worldwide; fruits and vegetables account for nearly 90% of the total horticultural production, and the production of vegetables increased from 101.2 million tons in 2004–05 to 184.40 million tons in 2017–18 (Horticultural Statistics at a Glance 2018).

While the total production is being constantly augmented, it is essential to make the market network efficient so that farming communities can get remunerative prices for their produce. The existence of an efficient marketing network for agricultural outputs is one of the prerequisites for ensuring optimal resource allocation in the agricultural sector. The efficient functioning of markets provides profitable prices to producers and fair prices to consumers (Mahalle, Shastri, and Kumar 2015). The integration of market prices of commodities across various markets is one of the stated objectives of many agricultural marketing reforms undertaken in the country. Well-integrated, efficient agricultural markets can allocate resources optimally and remove inefficiencies along the product value chain, thereby directly affecting farmer producer welfare (Thomas, Rajeev, and Sanil 2017).

The prices of some agricultural commodities—like tomato, onion, and potato—are highly volatile; this volatility originates primarily from production uncertainties and changes in the nature of demand. These demand characteristics have made prices vulnerable to violent fluctuations due to shocks in production. The potato, rightly assessed as the ‘king of vegetables’ by the FAO (2008), has been indicated as a crop that can help fight hunger and poverty in the future (Rana and Anwer 2018).

India is the second-largest potato producer worldwide; in 2019, it produced 52.59 million metric tons of the crop. But its price is volatile, and marketing is a major concern for farmers. Marketing costs are high because the marketing infrastructure is inadequate and there are many intermediaries between producer and consumer, and these reduce farmers' profits. Markets are geographically dispersed, but prices at these market centres exhibit long-run spatial linkages, suggesting that all the exchange locations are integrated and that the prices provide the relevant market signals (Ghosh 2010). The accuracy and speed at which a price change in one market is transmitted to other markets is taken as an indicator of market integration. The extent of integration gives signals for efficient resource allocation, considered essential for ensuring greater market efficiency, price stability, and food security (Muhammad and Mirza 2014). Therefore, the present study attempts to analyse the market efficiency by examining the transmission and spatial integration of selected potato markets.

Materials and methods

Based on secondary data, the study attempts to investigate the market efficiency of the potato crop.

Data collection

The analysis is based on time series monthly data on prices and arrivals collected from five major producing and marketing states. The markets are chosen on the criteria of the major assembling markets of the country: Agra market of Uttar Pradesh; Champadanga market of Hooghly in West Bengal; Firozpur market of Punjab; Azadpur Mandi of Delhi; and Pune market of Maharashtra. We collected monthly time series data on potato prices from July 2005 to June 2020 from the https://agmarknet.gov.in/ portal of the Ministry of Agriculture and Farmers Welfare, Government of India.

Data analysis

We employ several analytical tools to meet our objectives: the Cuddy–Della Valle index (CDVI), suggested by Cuddy and Della Valle (1978), to measure instability; the Augmented Dickey–Fuller (ADF) unit root test (Dickey and Fuller 1979) to check the series for stationarity; the trace ratio test statistics to test the number of cointegrating vectors; and the vector error correction method (VECM) to capture short-run disequilibrium situations as well as long-run equilibrium adjustments between the prices. The causal relationship is approached through the Granger causality test (Granger 1969). For determining the relative strength of causality effects beyond the selected duration, the impulse response function (IRF) is used, and to identify the price triggers in major influencing markets, the variance decomposition technique is applied.

Instability analysis

The coefficient of variation (CV) measures instability, but the CV overestimates the level of time series data characterized by long-term trends (Nimbrayan and Bhatia 2019).

$$CV = \frac{\text{Standard Deviation}}{\text{Mean}} * 100$$

This limitation is overcome by the CDVI, a modification of CV that de-trends and shows the exact direction of the instability (Anuja et al. 2013).

$$CDVI = CV\sqrt{1 - AdR^2}$$

where, adjusted R^2 = coefficient of determination

The ranges of CDVI (Sihmar 2014) are 0–15 (low instability), 15–30 (medium instability), and >30 (high instability).

Seasonality index

Seasonality is estimated from the average monthly data on prices, as the monthly data for several years is first converted into a monthly index using January as the base month every year. This partially removes the over-time trend in the data if there is any (Ali 2000). The monthly averages over the years are taken and then seasonality is estimated

$$S_i = \frac{(I_h - I_l)}{I_l} * 100$$

Where, I_h = Highest average monthly index value and I_l = Lowest average monthly index value

Stationarity test

Cointegration depicts the existence of a long-term equilibrium; before cointegration is tested, the time series need to be stationary, and the first step in time series analysis is to examine the stationarity of each individual time series selected. The ADF unit root test is conducted by augmenting the preceding three equations by adding the lagged values of the dependent variable ΔP_t. The ADF test here consists of estimating the following regression:

$$\Delta P_t = \alpha_0 + \delta_1 t + \beta_1 P_{t-1} + \sum_{j=0}^{q} \beta_1 \Delta P_{t-j} + \varepsilon_t$$

Where, $\Delta P_t = P_t - P_{t-1}$, $\Delta P_{t-1} = P_{t-1} - P_{t-2}$, $\Delta P_{n-1} = P_{n-1} - P_{n-2}$ etc.

P = the price in each market

α_0 = constant or drift

t = time trend variable

q = number of lag length selected based on Schwartz information criterion (SIC)

ε_t = pure white error term

The test for a unit root in the price series is carried out by testing the null hypothesis that β_1 (coefficient of P_{t-1}) is zero. The alternative hypothesis is that β_1 is less than 0. A non-rejection of the null hypothesis suggests that the time series under consideration is non-stationary (Gujarati 2004).

Johansen's cointegration method

Cointegration depicts a long-term relationship between variables; even if two or more series are non-stationary, they are said to be cointegrated if there exists a stationary linear combination of them. After establishing that the price series are stationary at the level or same order of differences, the maximum likelihood method of cointegration is applied to check the number of cointegrating vectors (Johansen 1988; Johansen and Juselius 1990). The null hypothesis of at most 'r' cointegrating vectors against a general alternative hypothesis of 'r+1' cointegrating vectors is tested by trace statistics. The number of cointegrating vectors indicated by the tests is an important indicator of the extent of the co-movement of prices. An increase in the number of cointegrating vectors implies an increase in the strength and stability of price linkages.

VECM for short-term relationship

The cointegration analysis reflects the long-run movement of two or more series, although they may drift apart in the short run. Once the series is found to be cointegrated, the next step is to find out the short-run relationship along with the speed of adjustment towards equilibrium using an error correction model, represented by the equations:

$$\Delta lnX_t = \alpha_0 + \sum \beta_{1i}\, \Delta lnY_{t-i} + \sum \beta_{2i}\, \Delta lnX_{t-i} + \gamma ECT_{t-1}$$

$$\Delta lnY_t = \beta_0 + \sum \alpha_{1i}\, \Delta lnX_{t-i} + \sum \alpha_{2i}\, \Delta lnY_{t-i} + \gamma ECT_{t-1}$$

where, ECT_{t-1} is the lagged error correction term

X_t and Y_t are the variables under consideration transformed through natural logarithm

X_{t-i} and Y_{t-i} are the lagged values of variables X and Y

The parameter γ is the error correction coefficient that measures the response of the regressor in each period to departures from equilibrium. The negative and statistically significant values of γ depict the speed of adjustment in restoring equilibrium after disequilibria, and if it is positive and zero, the series diverges from equilibrium (Saxena and Chand 2017).

Granger causality test

After undertaking the cointegration analysis of the long-run linkages of the various variables, and after identifying they are linked, the causal relationship between the prices series in the selected potato markets is approached through Granger's causality technique. If a variable Y is Granger-caused by variable X, it means that the values of variable X help predict the values of variable Y and vice versa. The Granger causality test conducted within the framework of a vector auto regression (VAR) model is used to test the existence of a long-run causal price relationship between markets and the direction of that relationship. The F-test is used to check whether the significance of changes in one price series affects another price series. This test also identifies the key market, i.e., the market that influences the price of all other markets (price leader). The causality relationship between two price series, based on the following pairs of ordinary least square (OLS) regression equations through a bivariate VAR, is given by the equations below:

$$\ln X_t = \sum_{i=1}^{m} \alpha_i \ln X_{t-i} + \sum_{j=1}^{m} \beta_j ln\, Y_{t-j} + \varepsilon_{1t}$$

$$\ln Y_t = \sum_{i=1}^{m} \alpha_i \ln Y_{t-i} + \sum_{j=1}^{m} \beta_j ln\, X_{t-j} + \varepsilon_{2t}$$

where,

X and Y are two different market prices series

ln stands for price series in logarithm form

t is the time trend variable

the subscript stands for the number of lags of both variables in the system

The null hypothesis in both equations is a test that ln X_t does not Granger-cause ln Y_t. In each case, a rejection of the null hypothesis will imply that there is Granger causality between the variables (Gujarati 2004).

Impulse response function

The Granger causality test does not determine the relative strength of causality effects beyond the selected duration. It is best to consider the time paths of prices after exogenous shocks, i.e., impulse responses, to interpret the model's implications for patterns of price transmission, causality, and adjustment (Vavra and Goodwin 2005). The IRF traces the effect of one standard deviation, or one unit shock, to one of the variables on current and future values of all the endogenous variables in a system over various time horizons (Rahman and Shahbaz 2013). We use the generalized impulse response function (GIRF), originally developed by Koop et al. (1996) and suggested by Pesaran and Shin (1998). The GIRF of an arbitrary current shock and historygiven in Equation for n = 0, 1, 2…..

$GIRFY(h, \delta, w_{t-1}) = E[Yt + h \mid w_{t-1}]$

Variance decomposition

The variance decomposition technique, applied to identify the price triggers in the major price-influencing markets, separates the variation in an endogenous variable into the shocks to the variables in the VAR. The variance decomposition technique provides information on the relative importance of each random innovation (price change in one market) in affecting the variables in the VAR (price changes in other markets).

Impulse responses trace out the moving average of the system, i.e., they describe how y_{it+T} responds to a shock in $e_{i,t}$; how variance decomposition measures the contribution of to the variability of y_{it+T}; how historical decomposition describes the contribution of shock $e_{i,t}$ to the deviations of y_{it+T} from its baseline forecast path (Canova 2007).

Results and discussion

Table 1 presents the instability and seasonality indices of potato prices in the selected markets.

Table 1 Instability and seasonality in potato prices in selected markets

Month	Agra			Hooghly			Firozpur			Delhi			Pune		
	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI	CV	CDVI	SI
Jan	52.54	40.14	1.45	67.87	58.50	1.36	55.77	53.11	1.47	54.24	46.81	1.43	38.80	31.51	1.16
Feb	39.86	29.53	1.47	48.29	39.65	1.58	45.01	43.95	1.60	36.92	30.67	1.47	33.78	22.74	1.26
Mar	41.09	28.73	1.22	51.57	42.87	1.38	52.90	49.92	1.31	42.57	35.63	1.30	36.31	22.16	1.24
April	48.06	37.76	1.12	48.84	38.89	1.01	72.16	67.49	1.29	43.27	37.32	1.15	37.56	24.20	1.06
May	47.27	38.78	0.94	45.84	34.71	0.83	64.18	56.69	1.01	45.19	39.34	1.03	35.02	25.54	0.92
June	46.27	37.17	0.83	49.79	39.00	0.82	54.95	43.87	0.81	38.50	34.43	0.83	33.15	24.93	0.91
July	47.63	40.54	0.76	48.12	42.47	0.83	50.08	46.15	0.68	33.30	29.16	0.73	37.36	32.10	0.91
Aug	52.48	47.32	0.78	50.70	45.32	0.82	59.23	56.16	0.68	40.41	35.38	0.74	39.07	34.95	0.92
Sept	53.64	49.55	0.78	50.49	46.77	0.82	61.87	56.89	0.65	40.85	36.63	0.67	38.56	33.83	0.89
Oct	54.45	49.83	0.74	47.91	43.17	0.78	57.17	53.01	0.67	40.06	36.78	0.64	40.58	34.13	0.86
Nov	50.96	47.49	0.79	45.16	39.58	0.78	51.82	49.13	0.78	41.51	37.38	0.75	41.12	38.55	0.90
Dec	44.89	39.71	1.10	54.69	50.15	0.99	50.22	46.96	1.06	50.21	44.22	1.24	42.05	38.87	0.96

CV-Coefficient of variation (%), CDVI- Cuddy-Della Valle index and SI-Seasonality Index

Table 2 Zero order correlation matrix for correlation in potato prices between selected markets

Markets	Agra	Hooghly	Firozpur	Pune	Delhi
Agra	1.0000				
Hooghly	0.8950*	1.0000			
Firozpur	0.7996*	0.7436*	1.0000		
Pune	0.9197*	0.9004*	0.7801*	1.0000	
Delhi	0.9150*	0.8256*	0.8266*	0.8636*	1.0000

*indicates $p<0.05$

Seasonality and instability analysis

If the value of the CDVI exceeds 30%, price instability is high; if it is less than 30%, instability is low to medium. The value of the CDVI is maximum in the month of January for Hooghly and Delhi, October for Agra, September for Firozpur and December for Pune, and it is minimum in March for Agra and Pune, May for Hooghly, June for Firozpur, and July for Delhi. From December to April-May, the value of the seasonality index exceeds 1; farmers receive above-average prices during this period.

Correlation analysis

The correlation matrix between the average potato prices is computed to determine the extent of integration among the selected markets (Table 2). The values from the correlation matrix, ranging from 0.8950 to 0.8636, are found highly significant and positive. This means the potato prices in selected markets moved together and are well integrated, i.e., the price differential in these markets is not more than the transport cost and, consequently, these markets are efficient.

Augmented Dickey–Fuller test (ADF)

To avoid fictitious results, it is imperative to check whether the variables are stationary; therefore, applying the ADF unit root test is a prerequisite of checking for integration. The results of the ADF unit root test 'at level' prices indicate that the t-statistic values for all the markets are less than 1%, 5%, and 10% level of critical values given by the MacKinnon statistical tables at levels, implying that these series are stationary and free from the consequences of a unit root (Table 3).

Johansen cointegration test

Based on the Johansen cointegration procedure, the cointegration between the selected markets is analysed through the unrestricted cointegration rank test (trace statistic), which indicates the presence of five cointegrating equations at 5% level of significance. The results show that potato prices in the selected markets have a long-run relationship and imply that the price linkages are strong and stable (Table 4).

Vector error correction model (VECM)

The VECM is employed to know the speed of

Table 3 ADF test to check stationarity of data

Markets	At level			Test critical values
	t-statistic	p-value*	Stationarity	
Agra	-4.71818	0.0001	Stationarity	
Hooghly	-4.4223	0.0004	Stationarity	1% level: -3.46721
Firozpur	-4.15025	0.001	Stationarity	5% level: -2.87764
Pune	-4.0526	0.0015	Stationarity	10% level: -2.57543
Delhi	-4.95756	0	Stationarity	

*MacKinnon (1996) one-sided p-values.

Table 4 Johansen cointegration test (trace) of price variation in potato markets

Null hypothesis	Eigenvalue	Trace statistic	Critical value	Prob.**
None *	0.30682	154.7538	69.81889	0
At most 1 *	0.247216	90.62242	47.85613	0
At most 2 *	0.120642	40.92639	29.79707	0.0018
At most 3 *	0.062384	18.42779	15.49471	0.0176
At most 4 *	0.040062	7.155161	3.841466	0.0075

Trace test indicates five cointegrating eqn(s) at the 0.05 level
*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

adjustments for long-run equilibrium among the selected markets. The coefficient of the error correction term denotes the speed of adjustment; higher the speed of adjustment, higher the chance of correction of any disequilibrium. It has been found highest when the prices at Agra and Firozpur markets are considered dependent upon the prices at other markets to the extent of, respectively, 30% and 14%, meaning that the chances of correction of any disequilibrium are high in these markets. When the Delhi and Pune markets are considered dependent, the speed of adjustment has been low or, respectively, 11.2% and 0.07%. Also, the prices at Delhi and Firozpur markets are influenced by their own monthly lags, whereas the prices at the Agra and Pune markets are influenced by their two-month lagged prices for long-run equilibrium.

$$\Delta lnAgra_t = -0.301ECT_{t-1} - 0.305\Delta lnAgra_{t-2} + 0.540lnDelhi_{t-1} + 0.211\Delta lnHooghly_{t-2} - 0.257\Delta lnPune_{t-2}$$

$$\Delta lnFirozpur_t = -0.139ECT_{t-1} - 0.291\Delta lnFirozpur_{t-1} + 0.117lnHooghly_{t-2} - 0.378\Delta lnPune_{t-2} + 0.383\Delta lnAgra_{t-1} + 0.525\Delta lnDelhi_{t-1}$$

$$\Delta lnDelhi_t = -0.112ECT_{t-1} - 0.418\Delta lnDelhi_{t-1} + 0.240lnFirozpur_{t-2} - 0.345\Delta lnPune_{t-2}$$

$$\Delta lnPune_t = -0.078ECT_{t-1} - 0.283\Delta lnPune_{t-2} - 0.283\Delta lnAgra_{t-2} + 0.328\Delta lnDelhi_{t-1} + 0.320\Delta lnHooghly_{t-1}$$

$$\Delta lnHooghly_t = -0.007ECT_{t-1} - 0.277\Delta lnPune_{t-2} + 0.381lnAgra_{t-1} + 0.252\Delta lnDelhi_{t-1} + 0.181\Delta lnFirozpur_{t-2}$$

The results of the error correction terms are interpreted to study the nature of the market and the movement towards long-run equilibrium, i.e., market efficiency. The negative and statistically significant values of the error correction term at the Agra, Firozpur, Delhi, and Pune markets depict the speed of adjustment in restoring the equilibrium after disequilibria, whereas the positive value of the error correction term in the Hooghly series depicts the divergence from the equilibrium.

Granger causality test

The causal relationship between the prices at the selected potato markets is approached through the Granger causality technique. It is found that the Delhi market prices influence the prices at the Agra and Firozpur markets and that these prices show bidirectional causality with the Hooghly and Pune markets (i.e., the prices are transmitted both ways). The Agra market causes unidirectional relationship with the Firozpur market, and it shows bidirectional causality with the Hooghly and Pune markets. The Firozpur market reveals bidirectional causality with the Hooghly and Pune markets. The Hooghly market prices influence the prices at the Pune market and these show a bidirectional relationship with the prices at the Firozpur, Delhi, and Agra markets. The prices at the Pune market show a bidirectional causality with the prices at the Delhi, Agra, and Firozpur markets. This reveals a strong market integration between the prices of the selected potato markets, and that the Delhi market is the key influencer of the prices at all other selected potato markets (Table 5, Figure 1).

Impulse response function (IRF)

Using the Granger causality technique shows that the Delhi market is key, and we interpret the response of other markets to changes in the prices at the Delhi

Table 5 Results of pair-wise Granger causality test of selected potato markets

Null Hypothesis:	F-Statistic	Probability
HOOGHLY does not Granger cause AGRA	4.705	0.010
AGRA does not Granger cause HOOGHLY	19.273	0.000
FIROZPUR does not Granger cause AGRA	0.401	0.671
AGRA does not Granger cause FIROZPUR	14.111	0.000
DELHI does not Granger cause AGRA	17.608	0.000
AGRA does not Granger cause DELHI	1.779	0.172
PUNE does not Granger cause AGRA	7.686	0.001
AGRA does not Granger cause PUNE	18.812	0.000
FIROZPUR does not Granger cause HOOGHLY	5.137	0.007
HOOGHLY does not Granger cause FIROZPUR	7.831	0.001
DELHI does not Granger cause HOOGHLY	17.084	0.000
HOOGHLY does not Granger cause DELHI	3.180	0.044
PUNE does not Granger cause HOOGHLY	2.480	0.087
HOOGHLY does not Granger cause PUNE	10.145	0.000
DELHI does not Granger cause FIROZPUR	21.293	0.000
FIROZPUR does not Granger cause DELHI	0.266	0.767
PUNE does not Granger cause FIROZPUR	9.626	0.000
FIROZPUR does not Granger cause PUNE	5.705	0.004
PUNE does not Granger cause DELHI	6.541	0.002
DELHI does not Granger cause PUNE	28.454	0.000

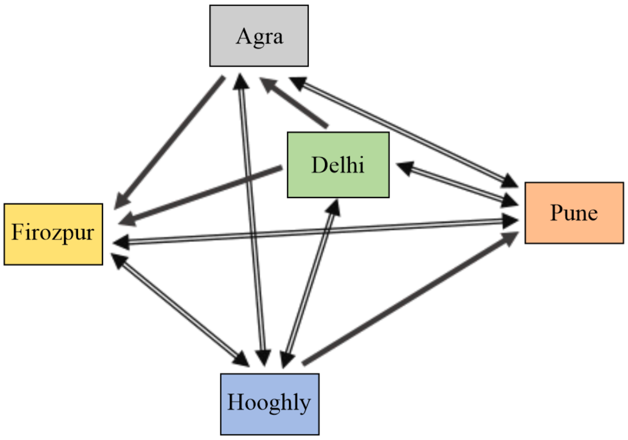


Figure 1 Unidirectional and bidirectional relationship between markets

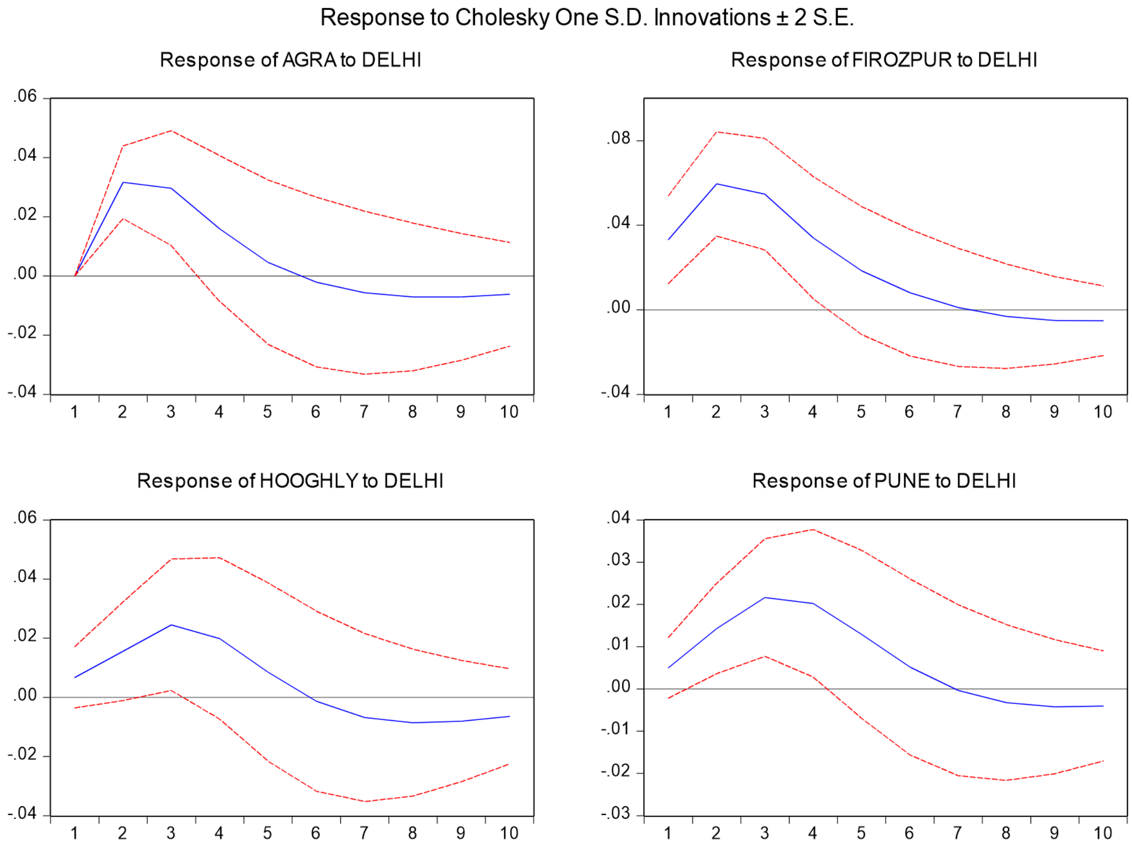
*Single arrow shows a unidirectional relationship, *Double arrow shows a bidirectional relationship

market with the help of the IRF and variance decomposition. The IRF describes how much and to what extent a standard deviation shock in one of the markets—say, Delhi—affects prices in all the integrated markets over a period of 10 months (Figure 2).

When a standard deviation shock is given to the Delhi market, an immediate, high response is noticed in all the other markets. The Agra and Firozpur markets peaked in the second month and started declining after the third month. The Hooghly and Pune markets peaked in the third month and started declining after the fourth month. The response kept declining thereafter and became negative in all the markets. This shows that a shock arising in the Delhi market is transmitted to all the other markets and the response is higher in the following months. The response of the Agra and Firozpur markets has been stronger than in others.

Variance decomposition

The variance decomposition indicates the amount of information each variable contributes to the other variables in the VAR, and it determines how much of the forecast error variance of variables can be explained by the exogenous shocks to the other variables. The results reveal that in the short run 100% of the forecast error variance in Delhi is explained by the variable itself, which means that the other variables



Red line refers to 95% confidence interval
Blue line refers to impulse response function

Figure 2 Response of other markets to change in Delhi market prices

Table 6 Variance decomposition of Delhi market

Period	S.E.	Delhi	Agra	Firozpur	Hooghly	Pune
1	0.086	100.000	0.000	0.000	0.000	0.000
2	0.135	97.326	1.543	0.031	0.345	0.755
3	0.167	92.375	3.737	0.021	1.835	2.031
4	0.186	86.356	6.035	0.034	4.039	3.535
5	0.197	81.048	7.886	0.051	6.052	4.964
6	0.203	77.365	9.070	0.057	7.353	6.154
7	0.206	75.262	9.672	0.056	7.964	7.046
8	0.208	74.256	9.900	0.058	8.146	7.639
9	0.208	73.849	9.947	0.073	8.152	7.980
10	0.209	73.698	9.934	0.098	8.129	8.141

in the model do not substantially influence the Delhi market (Table 6). The other markets have a robust exogenous impact, i.e., these do not influence Delhi at all in the short run. Even in the second period, the influence of other markets is low, implying that these variables exhibit strong exogeneity and have a weak influence on the other markets in the future. In the long run, 73.69% of the forecast error variance of the Delhi market is explained by the market itself. Thus, the influence of the Delhi market is strong in the short run and in the future, and the influence of the other markets, though rising every year, is weak overall.

Conclusions

The potato crop has been encountering high volatility in prices for the past few years, and marketing, which is critical for the crop, is a major concern for farmers. This study analyses market integration by examining the price transmission and spatial integration of selected potato markets. The accuracy and speed at which price changes in one market are transmitted to other markets is considered an indicator of market integration. The extent of integration gives signals for efficient resource allocation, which is considered essential for improving market efficiency.

The study reveals that in the selected markets, potato prices are unstable in January, October, September, and December, and from December to April-May farmers receive an above-average price. The correlation analysis shows that prices in the markets moved together, and they are well integrated, which implies that the price differential in the selected markets is not more than the transport cost. This signals that the markets are well integrated and efficient. The price series in the selected markets are stationary, and the unrestricted cointegration test indicates that potato prices in the chosen markets have a long-run relationship. The trace test indicates five cointegrating equation at the 0.05 level. Their own monthly lags influence the prices at the Delhi and Firozpur markets, whereas the Agra and Pune markets are influenced by their two-month lagged prices for long-run equilibrium.

The speed of adjustment is highest in the Agra (30%) and Firozpur (14%) markets, which means that in these markets the chances of correction of any disequilibrium are high. Granger causality reveals that Delhi is the key influencer of prices in the other selected markets: a standard deviation shock given to the Delhi market stimulates an immediate, high response in all the other markets; the impulse response increases initially, but it declines after peaking and eventually becomes negative in all the markets. This shows that if a shock arises in the Delhi market it is transmitted to all the other markets with a higher response in the following months. The variance decomposition reveals that the influence of the Delhi market is strong in the short run and in the future, whereas the influence of other markets, though rising every year, is weak. It is concluded that prices fluctuate by season, and these price fluctuations can be managed by developing proper storage facilities and an efficient supply chain management system. A robust monitoring mechanism on potato prices and arrival should be developed in the Delhi market to check manipulation.

References

Agmarknet. 2020. Agmarknet portal of Ministry of Agriculture and Farmers Welfare, Government of India, India. *https://agmarknet.gov.in/*

Ali, M. 2000. Dynamics of vegetable production, distribution and consumption in Asia. Asian Vegetable Research and Development Center, Shanhua, Taiwan. *https://pdf.usaid.gov/pdf_docs/pnacj643.pdf*

Anuja, A R, A Kar, G Jha, and R Kumar. 2013. Price dynamics and market integration of natural rubber under major trade regimes of India and Abroad. Indian Journal of Agricultural Sciences 83 (5): 555–560. *https://www.researchgate.net/publication/290011033*

Canova, F. 2007. Methods for Applied Macroeconomic Research. Princeton University Press, England. *https://pdfs.semanticscholar.org/d0c1/d0452b857878515c4d4544af886d86d32f2c.pdf?_ga=2.230860060.240527957.1604480091–1905022333.1588181860*

Cuddy, J D A, and P A Della Valle. 1978. Measuring of Instability of Time Series Data. *Oxford Bulletin of Economics and Statistics* 40 (1): 79–85. *https://sci-hub.do/10.1111/j.1468–0084.1978.mp40001006.x*

Dickey, D A, and W A Fuller. 1979. Distribution of the estimators for the autoregressive time series with a unit root. *Journal of the American Statistical Association* 74: 427–31. *https://www.researchgate.net/publication/243644934*

FAO. 2008. New Light on a Hidden Treasure. An End-of-Year Review (International Year of the Potato-2008). Food and Agriculture Organization of the United Nations, Rome. *http://www.fao.org/potato-2008/pdf/iypbook-en.pdf*

Ghosh, M. 2010. Spatial price linkages in regional food grain markets in India. *The Journal of Applied Economic Research* 4 (4): 495–516. *https://www.researchgate.net/publication/270709649*

Granger, C W J. 1969. Investigating causal relations by econometric models and cross- spectral methods. *Econometrica* 37 (3): 424–438. *http://tyigit.bilkent.edu.tr/metrics2/read/Investigating %20%20*

Causal%20Relations%20by%20Econometric%20Models%20and%20Cross-Spectral%20Methods.pdf

Gujarati, D N. 2004. *Basic Econometrics*. 4th edition. The McGraw-Hill Companies, United States. *http://www.research-excellence.com/ebooks/Basic%20Econometrics.pdf*

Horticulture Statistics Division, Department of Agriculture, Cooperation & Farmers' Welfare, Ministry of Agriculture and Farmers' welfare, Government of India. 2018. Horticultural Statistics at Glance, New Delhi. *http://agricoop.nic.in/sites/default/files/Horticulture%20Statistics%20at%20a%20Glance-2018.pdf*

Johansen, S. 1988. Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control* 12 (2–3): 231–254. *http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=BDFB210A619A830434F2EC37B39356F4?doi=10.1.1.612.1658&rep=rep1&type=pdf*

Johansen, S, and K Juselius. 1990. Maximum likelihood estimation and inference on cointegration: with applications to the demand for money. *Oxford Bulletin of Economics and Statistics* 52 (2): 169–210. *https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1468–0084.1990.mp52002003.x?src=getftr*

Koop, G, M H Pesaran, and S M Potter. 1996. Impulse response analysis in non-linear multivariate models. *Journal of Econometrics* 74: 119–148. *https://www.academia.edu/3484329/*

Mahalle, S L, S Shastri, and S Kumar. 2015. Integration of Wheat Markets in Maharashtra. *Agricultural Economics Research Review* 28(1): 179–187. *https://pdfs.semanticscholar.org/995d/465eedabd748743961eb9893f9361f6d0682.pdf*

Muhammad, A, and T Mirza. 2014. The Effects of Market Integration on Rice Market Performance and its Implication on National Food Security in Indonesia. *Journal of Economics and Sustainable Development* 5 (23): 107–111. *https://www.iiste.org/Journals/index.php/JEDS/article/download/16762/17117*

Nimbrayan, P K, and J K Bhatia. 2019. Growth and Instability in Area, Production and Productivity of Barley in Haryana vis-à-vis India. *Current Journal of Applied Science and Technology* 35 (6): 1–8. *https://www.researchgate.net/publication/333844356*

Pesaran, M H, and Y Shin. 1998. Generalized impulse response analysis in linear multivariate models. *Economics Letters* 58 (1): 17–29. *http://www.sciencedirect.com/science/article/pii/S0165–1765(97)00214–0*

Rahman, M M, and M Shahbaz. 2013. Do imports and foreign capital inflows lead economic growth? Cointegration and causality analysis in Pakistan. *South Asia Economic Journal* 14 (1): 59–81. *https://www.researchgate.net/publication/50857252*

Rana, R K, and M E Anwer. 2018. Potato production scenario and analysis of its total factor productivity in India. *Indian Journal of Agricultural Sciences* 88 (9): 1354–61. *https://www.researchgate.net/publication/327892140*

Saxena, R, and R Chand. 2017. Understanding the Recurring Onion Price Shocks: Revelations from Production-Trade-Price Linkages. Policy Paper 33, ICAR-National Institute of Agricultural Economics and Policy Research (NIAP), New Delhi. *http://www.niap.res.in/upload_files/policy_paper/Policy%20Paper%2033.pdf*

Sihmar, R. 2014. Growth and Instability in Agricultural Production in Haryana: A District level Analysis. *International Journal of Scientific and Research Publications* 4 (7):1–12. *http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.569.408&rep=rep1&type=pdf*

Thomas, L, P Rajeev, and P C Sanil. 2017. Impact of Market Reforms on Price Integration: A Study of Wholesale Spice Markets in India. *Economic Affairs* 62 (3): 427–433. *http://ndpublisher.in/admin/issues/EAv62n3j.pdf*

Vavra, P, and B Goodwin. 2005. Analysis of Price Transmission along the Food Chain. OECD Food, Agriculture and Fisheries Working Paper No 3. OECD Publishing, France. *http://dx.doi.org/10.1787/752335872456*

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Impact of natural resource management technologies on technical efficiency in sorghum cultivation: application of meta-frontier and endogenous switching regression model

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Abstract This study assesses the impact of the adoption of natural resource management (NRM) technologies on sorghum production in the drought-prone areas of Indian state of Karnataka, using plot-level data. The key factors affecting adoption are access to credit, extension services, and social networks. The bias-corrected technical efficiency scores and the meta-technology ratio indicate that efficiency can be improved by 30%. The result of endogenous switching regression shows that the average treatment effect on treated is -0.24, suggesting a 13%. reduction in production efficiency. Adopting NRM technologies could enhance production and farmer livelihoods in drought-prone areas.

Keywords Impact assessment, natural resource management, sorghum, meta-frontier

JEL codes Q01, Q5, Q15

Soil degradation (Biswas et al. 2019) and climate change (Krishnakanth and Nagaraja 2020) threaten agricultural sustainability in Karnataka, one of the most drought-prone states of the country (Nagaraja, Somashekar, and Kavitha 2011). Severe to moderate droughts are frequent in Karnataka (Ray et al. 2015; KSNDMC 2017); more than 70% of the cultivated area is rainfed, and the droughts often result in partial or complete crop failure (Biradar and Sridhar 2009).

The crop production potential is limited also by erratic and uncertain rainfall, with higher degree of spatial temporal variability; depleting groundwater resources; inadequate infrastructure; low input use and technology adoption; and eroding natural resources. The average yield of most common crops is between two and five times less than their optimal yield level (Wani et al. 2011). The crop loss due to water erosion alone is INR 32,429 million (at 2014–15 prices), the second highest in the country after Madhya Pradesh (TERI 2018).

Natural resource management (NRM) technologies enhance productivity by conserving soil moisture, improving soil health, and encouraging the use of quality inputs and improved seeds (Kerr and Sanghi 1992; Gebrernichael et al. 2005; Rajkumar and Satishkumar 2014; Bhattacharyya et al. 2015; Wolka, Mulder, and Biazin 2018). The NRM technologies recommended in the region are broad bed and furrow, contour bunding, graded bunding, compartment bunding, ridges and furrows, contour cultivation, and set-furrow cultivation (Pathak, Laryea, and Singh 1989; Vittal et al. 2004; Sharma and Guled 2012; Mishra, Singh, and Kumar 2018).

Contour bunding is the most widely practised technique in the semi-arid tropics (Bhattacharyya et al. 2015; Narayan, Biswas, and Kumar 2019; Naveena, Shivaraj, and Nithin 2019; Pathak et al. 1989). Soil bunds help in reducing soil loss and run-off and in improving soil moisture and fertility and, in turn, increasing crop productivity (Gebrernichael et al. 2005; Kerr and

Sanghi 1992; Rajkumar and Satishkumar 2014). Using soil bunds positively influences crop productivity.

The state government has been trying to scale the adoption of conservation technologies, but private or voluntary adoption has been low (Reddy, Hoag, and Shobha 2004; Bhattacharyya et al. 2015), and there is a need to understand the factors that affect the adoption of conservation technologies and their effect on production performance. Few studies have used plot-level data and the meta-frontier approach to compare the technical efficiency (TE) of adopters and non-adopters in India, however, to the best of our knowledge.

This study assesses the impact of the soil bunds technique on efficiency and explores the linkages between NRM and technical efficiency (TE). We use the endogenous switching regression (ESR) model to control for the heterogeneity effects of observed and unobserved factors. To estimate the bias-corrected TE scores, we use the double bootstrap data envelopment analysis (DEA) technique (Simar and Wilson 2007). To identify the factors affecting the TE for each group, we use bootstrapped regression.

This paper will help policymakers to design programmes for increasing the adoption rate of NRM technologies and, thereby, sustain the natural resources and livelihoods of resource-poor farmers in the region.

Data and study area

We purposively selected a region of Karnataka that is a drought hotspot and where the frequency of drought is projected to increase in the future (BCCI-K 2011). We randomly selected four districts—Tumukuru, Koppal, Bidar, and Gadag—as first-stage sampling units. At the second stage, we selected a sub-watershed from each district. From each watershed (treated area), we randomly selected plots from net planning reports (a net planning report forms part of a detailed project report/feasibility report, which contains information on all the plots of the farmers in a watershed). Sorghum is an important food and fodder crop in drought-prone areas; this way, we chose 193 sorghum-growing plots for a detailed survey (including household-level features), and we also randomly selected 251 control plots (untreated areas) in the vicinity of treated areas. The variables selected for this study are guided by the relevant literature and the understanding of watershed management in the region.

Methodology

Generally, to estimate TE, the two-step DEA approach is used, but Simar and Wilson (2007) argue that it does not account for the underlying data-generating process (DGP), and its efficiency estimates are serially correlated and these lead to statistically invalid inferences. The implication is that the efficiency estimates of the two-step DEA approach are biased, and these positively exaggerate the level of efficiency within a sample.

Double bootstrap data envelopment analysis (DEA) method

In the double bootstrap DEA method, the estimates of efficiency scores are bias-corrected–the idea underlying bootstrapping is simply to simulate the sampling distribution of interest by mimicking the DGP—and policymakers can view the results with more confidence. Therefore, we use the double bootstrap DEA method.

$$TE_j = min\{: \delta X_J \in L(Y_j)\}$$

$$TE_j = \min_{\delta,\lambda} \delta$$

St $\sum_{j=1}^{n} \lambda_{kj} y_{kj} \geq y_{ko}$

$$\sum_{j=1}^{n} \lambda_{kj} x_{mkj} \leq \delta x_{mko} \; \forall \; m$$

The DEA can be formulated with the assumption of either constant returns to scale (CRS) $\lambda_{kj} \geq 0$ or variable returns to scale (VRS) $\Sigma_{j=1}^{n} \lambda_{kj} = 1, \lambda_{kj} \geq 0$. Similarly, we can define an input-oriented DEA for meta-frontier efficiency estimation and use a bootstrapping technique to correct biased efficiency scores (δ_{kj}):

$$\hat{b}_k = \frac{1}{T} \sum_{t=1}^{T} \delta_{kj}^{*(T)} - \delta_{kj}$$

Where $\hat{b}_k$ is bias, the bias-corrected TE scores can be given as

$$\bar{\bar{\delta}}_{kj} = \delta_{kj} - \hat{b}_k$$

Estimation of meta-frontier efficiency

The meta-frontier is 'the envelope of commonly conceived classical production functions' (Hayami and Ruttan 1971). The meta-frontier model groups all farmers by their level of adoption. The model indicates the sources of technological heterogeneity and enables the estimation of comparable technical efficiencies for firms operating under different technologies (Battese, Rao, and O'Donnell 2004).

The meta-frontier is an envelope—it considers all the group frontiers (Moreira and Bravo-Ureta 2010; Le, Vu, and Nghiem 2018)—therefore, the TE estimated employing the meta-frontier model is lower than the TE estimated using the group-specific frontier. One implication is that there exists a non-negative distance—known as the meta-technology ratio (MTR), and defined as the 'gap in technology access to a given group relative to technology available to all groups taken together, i.e. global or meta-frontier efficiency'.

Higher the value of the MTR, less the gap between the group frontier and the meta-frontier (O'Donnell, Rao, and Battese 2008). Therefore, there is a need to shift to a higher-MTR technology or group or increase production by switching to a higher-MTR group.

$$MTR^k(.) = \frac{\bar{\bar{\delta}}_G}{\bar{\bar{\delta}}_K}$$

where, $\bar{\bar{\delta}}_G$ is bias-corrected meta-frontier or global TE, and $\bar{\bar{\delta}}_K$ is bias-corrected group-specific TE.

Determinants of technical inefficiency

Efficiency scores are not generated by a censoring DGP but are fractional data-generating processes; therefore, it is not appropriate to use Tobit to explain the determinants of efficiency (Banker and Natarajan 2008; McDonald 2009). Unbiased parameter estimates can be yielded by bootstrapped truncated regression:

$$\bar{\bar{\delta}}_{kj} = \alpha + Z_j\phi + \mu_j;\ j=2;\ \mu_j \sim N(0,1)$$

Where,

$\bar{\bar{\delta}}_{kj}$ = group-specific efficiency

Z_j=set of variables expected to be influencing efficiency

Endogenous switching regression model for impact assessment

The decision to adopt NRM technologies is a standard dichotomous choice model assuming that the farmer is risk-neutral and they compare the net benefit from the NRM technologies in making their decision. Assume that TIE_{iNRM} indicates the technical inefficiency—the inverse of technical efficiency—of a farmer with the adoption of NRM technologies, TIE_{iNA} indicates technical inefficiency with non-adoption, and a farmer will choose NRM if $TIE_{iNRM} < TIE_{iNA}$.

$$\text{Adopter: } TIE_{iNRM} = X_i\beta_{NRM} + \mu_{iNRM};\ \mu_{iNRM} \overset{iid}{\rightarrow} N(0,1) \quad \text{... (1)}$$

$$\text{Non-adopter: } TIE_{iNA} = X_i\beta_{NA} + \mu_{iNA};\ \mu_{iNA} \overset{iid}{\rightarrow} N(0,1) \quad \text{... (2)}$$

where, X_i is a vector of explanatory variables including personal and household-level characteristics, plot features, perception (risk of crop failure and benefits of NRM technologies), inputs of crop production, and other institutional variables; β_{NRM} and β_{NA} are vectors of parameters to be estimated.

Assume that T_i^* is a latent variable that indicates that adopting NRM technologies yield positive net benefits. It can be expressed as a function of farmers' characteristics, say W, as given below:

$$T_i^* = \gamma' W + \varepsilon_i;\ \varepsilon_i \overset{ND}{\rightarrow} (0, \sigma_\varepsilon^2)$$

$$T_i = 1 \text{ if } T_i^* > 0$$

$$T_i = 0 \text{ if } T_i^* < 0 \quad \text{...(3)}$$

where, T_i^* is a dichotomous variable, taking value 1 for the adopter of NRM technologies and 0 for non-adopters. The γ' is a vector of parameters to be estimated. The captures measurement errors as well as unobservable factors influencing technical inefficiency.

This study aims to estimate the impact of the adoption of NRM technologies on TE; however, in cross-section data, there is a problem of counterfactuals–the baseline data for adopters is absent. Another problem is the selection bias, which stems from the inability to observe the managerial and technical abilities of farmers (Abdulai and Huffman 2014). If the unobservable factors influence the error terms of outcome (μ_i) and selection equation (ε_i), the influence will lead to a non-zero correlation coefficient—$corr(\varepsilon,\mu) = \rho \neq 0$—and the estimates of the ordinary least squares method will be biased.

In assessing impact, dealing with selection bias is critical; therefore, to examine the determinants of the adoption of NRM technologies and the impact of adoption on technical inefficiency, we employ the endogenous regime switching(ERS) model—a parametric approach that accounts for selection bias from observed as well as unobserved variables (Maddala 1986). To capture the differential impact in the ESR model, we group all the observations by adopters of NRM technologies and non-adopters. Two regimes can be given as follows:

Regime 0: $TIE_{iNA} = X_i\beta_{NA} + \mu_{iNA}$; $T_i = 0$

Regime 1: $TIE_{iNRM} = X_i\beta_{NRM} + \mu_{iNRM}$; $T_i = 1$ …(4)

Are Equations 1, 2, and 4 the same? In Equations 3 and 4, all the variables could be the same, but for the identification of the selection equation from the outcome equations, there should be at least one variable (instrumental variable, IV) *W* in which is not included in *X*. When there is non-zero correlation between the error terms ..... and μ_{iNRM}, μ_{iNA}, these error terms follow a trivariate normal distribution with zero mean and variance and covariance matrix (Lokshin and Sajaia 2004):

$$\Omega = \begin{bmatrix} \sigma^2_{NRM} & \sigma_{NRM,NA} & \sigma_{NRM,\varepsilon} \\ \sigma_{NRM,NA} & \sigma^2_{NA} & \sigma_{NA\varepsilon} \\ \sigma_{NRM,\varepsilon} & \sigma_{NA,\varepsilon} & \sigma^2_{\varepsilon} \end{bmatrix} \quad \dots(5)$$

where, the diagonal terms are variances and off-diagonal terms are co-variances. The selection bias arising due to observable variables is taken care of in Equation 4, but we need to estimate and test the inverse Mills ratio (IMR) for both adopters and non-adopters for selection bias from the unobserved variables. The expected values of truncated error can be obtained as follows:

$$E(\mu_{NA}|T=0) = \sigma_{NA\varepsilon}\frac{-\phi(\frac{W'\gamma}{\sigma})}{1-\Phi(\frac{W'\gamma}{\sigma})} \equiv \sigma_{NA\varepsilon}\lambda_{NA} \quad \dots(6)$$

$$E(\mu_{NRM}|T=1) = \sigma_{NRM\varepsilon}\frac{-\phi(\frac{W'\gamma}{\sigma})}{1-\Phi(\frac{W'\gamma}{\sigma})} \equiv \sigma_{NRM\varepsilon}\lambda_{NRM} \quad \dots(7)$$

where, ϕ is the standard normal probability density (PDF) function and Φ is the standard normal cumulative distribution function (CDF). λ_{NA} is the IMR for non-adopters and λ_{NRM} is the IMR for adopters, representing selectivity. To account for selectivity bias, IMRs are added in Equation 8:

Regime 0: $TIE_{iNA} = X_i\beta_{NA} + \sigma_{NA\varepsilon}\lambda_{NA} + \mu_{iNA}$; $T_i = 0$

Regime 1: $TIE_{iNRM} = X_i\beta_{NRM} + \sigma_{NRM\varepsilon}\lambda_{NRM} + \mu_{iNRM}$; $T_i = 1$ …(8)

The residuals in the two-stage estimation method are heteroscedastic, and it is difficult to get consistent standard errors without performing a complex weighting procedure (Lokshin and Sajaia, 2004); therefore, we use the full information maximum likelihood estimation (FI-MLE) method for the simultaneous estimation of the selection and outcome equations. Moreover, the FI-MLE method yields consistent and asymptotically efficient parameters (Maddala, 1986), and the signs and significance levels of the correlation coefficient of the error terms between the selection and outcome equations have an economic interpretation.

If $\rho_{NA\varepsilon}$ and/or $\rho_{NRM\varepsilon}$ is significantly different from 0, the presence of selectivity bias is indicated, and the use of ESR is appropriate. If $\rho>0$, the selection bias is negative; it indicates that farms at above-average technical inefficiency are less likely to adopt NRM technologies. If $\rho<0$, the selection bias is positive; it indicates that farms at below-average technical inefficiency are more likely to adopt NRM technologies (Abdulai & Huffman, 2014). If the correlation coefficients have the same sign, hierarchical sorting is indicated: adopters have below-average technical inefficiency compared to non-adopters—irrespective of the adoption decision. An alternate sign indicates that farmers adopt NRM technologies according to comparative advantage (Alene and Manyong 2007). The expected value of outcome for an adopter is given by:

$E(TIE_{NRM}|T = 1) = X_i\beta_{NRM} - \sigma_{NRM\varepsilon}\lambda_{NRM}$ …(9)

Term $\sigma_{NRM\varepsilon}\lambda_{NRM}$ shows sample selectivity, indicating that farms that adopted NRM technologies may behave differently from average farms with identical features because of unobserved variables (Maddala 1986). If the same farm had not adopted NRM technologies, the expected outcome would have been

$$E(TIE_{NA}|T = 1) = X_i\beta_{NA} - \sigma_{NA\varepsilon}\lambda_{NRM} \quad ...(10)$$

Now, the average treatment effect on the treated (ATT) can be given (Lokshin and Sajaia 2004):

$$ATT = E\ (TIE_{NRM}|T = 1) - (TIE_{NA}|T = 1) = X_i(\beta_{NRM} - \beta_{NA}) + \lambda_{NRM}\ (\sigma_{NRM\varepsilon} - \sigma_{NA\varepsilon}) \quad ...(11)$$

Similarly, the average treatment effect on the untreated (ATU) can be given:

$$ATU = E\ (TIE_{NRM}|T = 0) - (TIE_{NA}|T = 0) = X_i(\beta_{NRM} - \beta_{NA}) + \lambda_{NA}\ (\sigma_{NRM\varepsilon} - \sigma_{NA\varepsilon}) \quad ...(12)$$

Further, the base heterogeneity effects can be estimated:

$$BH_1 = E\ (TIE_{NRM}|T = 1) - E(TE_{NRM}|T = 0) \quad ...(13)$$

$$BH_2 = (TIE_{NA}|T = 1) - E(TE_{NA}|T = 0) \quad ...(14)$$

Results and discussion

There is no difference between adopters and non-adopters on most household-level characteristics (except the number of livestock units, access to credit, and off-farm income) (Table 1). The number of livestock units is higher for adopters than non-adopters because the availability of fodder is better in treated areas—soil bunds are stabilized by growing grass species, which supply additional fodder (Arya, Panwar, and Yadav 2011). Also, project implementing agencies (PIA) distribute cross-breed cows in watershed areas. Higher access to credit also can be attributed to efforts made by PIAs to create awareness about ongoing financial assistance schemes and link farmers in self-help groups (SHG) to formal banks.

In the case of plot-level features, adopters differ from non-adopters in terms of slope, soil erosion, and fertility levels. The plots of around 90% of non-adopters and 64% of adopters had a high slope and soil erosion was high. The perception of the risks of crop failure and the benefits of conservation technologies differed between adopter and non-adopter farms. Extension and training services officers had conducted more exposure visits and training programmes for adopter farmers than non-adopters, because before watershed activities are executed—and in the capacity-building phase—PIAs try to persuade farmers of the benefits of NRM technologies by taking them to visit model watersheds, and they conduct training programmes during the phases of watershed development. At the time of watershed activities, many committees and groups are formed for the effective execution of conservation measures, and the social networks of adopter farmers are better than that of non-adopters. Further, the input utilization of adopters is statistically different than that of non-adopters.

Distribution of technical efficiency

The mean group-specific technical efficiency (GSTE) is 0.83 for adopters and 0.84 for non-adopters (Table 2). The meta-frontier technical efficiency (MFTE) is 0.68 for adopters and 0.53 for non-adopters. The MFTE is less than the GSTE because, in the case of the GSTE, an individual farm faces only the group frontier but, in the case of the meta-frontier, the farm is compared with the global frontier. The MTR for adopters is 0.82, higher than the 0.63 for non-adopters, and it shows that a shift in technology can enhance efficiency by 30.16% (Table 2).

The two-sample Kolmogorov–Smirnov test rejected the CRS model (0.61712, p-value <0.00); therefore, we discuss the results of the VRS model. Moreover, with the plot-level data, the VRS model seems more realistic than the restrictive CRS model. The frequency distribution of the GSTE shows that the efficiency scores of around 79% of the adopter plots and 84% of the non-adopter plots lie in the 70–100% range. The efficiency score exceeds 90% for around 46% of the adopter plots and 42% of the non-adopter plots in the GSTE (Table 3).

Factors affecting technical inefficiency

The results of the factors affecting the technical inefficiency of sorghum production (Table 4) show that age, dependency ratio, number of livestock units, farm assets index and access to credit are associated with less technical inefficiency; these factors enhance production efficiency. The farm assets index shows the ownership of farm implements; farmers who rank high on the higher farm assets index can carry out agricultural operations in time, particularly at critical growth stages, which in turn positively affects efficiency. Our results are in line with Vortia et al. (2019), which reports a positive relationship between farm mechanization and efficiency. Access to credit has a positive and statistically significant effect on efficiency as it enables farmers to utilize improved or new technologies and a better mix of quality inputs for crop production (Laha 2013).

Table 1 Sample plots (descriptive summary)

		Sample (N=444)	Adopter (N=193)	Non-Adopters (N=251)	p-value
Household-level characteristics					
Head (male=1; otherwise 0)		0.82(0.39)	0.79 (0.41)	0.84 (0.37)	0.269
Age (years)		50.0 (12.3)	50.2 (11.7)	49.8 (12.8)	0.717
Education (number of schooling years)		5.3 (4.5)	5.3 (4.3)	5.3 (4.6)	0.983
Family size (number of members)		5.1 (1.8)	5.1 (1.8)	5.0 (1.8)	0.716
Size of landholding (ha)		2.5 (2.0)	2.4 (1.9)	2.5 (2.1)	0.903
Livestock (number of animals)		4.0 (2.7)	5.0 (2.9)	4.0 (2.5)	0.001
Off-farm income (if yes=1; otherwise 0)		279 (62.8)	166 (86.0)	113 (45.0)	<0.001
Dependency ratio (area per capita)		0.5 (0.5)	0.5 (0.4)	0.5 (0.5)	0.601
Farm asset index#		0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.902
Access to credit		271 (61.0)	144 (74.6)	127 (50.6)	<0.001
Farm-/plot-level characteristics					
Size of plots		0.8 (0.6)	0.8 (0.6)	0.8 (0.5)	0.562
Number of plots		3.0 (1.9)	3.1 (2.1)	2.9 (1.7)	0.281
Tenure (if own=1; otherwise 0)		310 (69.8)	129 (66.8)	181 (72.1)	0.273
Slope of plot (if high=1; otherwise 0)		309 (69.6)	174 (90.2)	135 (53.8)	<0.001
Type of soil (if red=1; otherwise 0)		137 (30.9)	72 (37.3)	65 (25.9)	0.013
Type of soil (if black=1; otherwise 0)		208 (46.8)	92 (47.7)	116 (46.2)	0.835
Soil erosion perception (if high=1; otherwise 0)		262 (59.0)	124 (64.2)	138 (55.0)	0.061
Soil erosion perception (if medium=1; otherwise 0)		92 (20.7)	37 (19.2)	55 (21.9)	0.556
Fertility of plot (if high=1; otherwise 0)		178 (40.1)	96 (49.7)	82 (32.7)	<0.001
Fertility of plot (if medium=1; otherwise 0)		246 (55.4)	89 (46.1)	157 (62.5)	0.001
Perception of farmers					
Risk perception (chances of crop failure)		4.8 (1.4)	5.4 (1.5)	4.3 (1.1)	<0.001
Benefit perception index# (number)		3.3 (0.7)	3.2 (0.7)	3.4 (0.7)	0.01
Extension and training services					
Number of visits of KVK and RSK		3.0 (1.6)	3.0 (1.5)	3.0 (1.6)	0.731
Exposure visits (If yes=1; otherwise 0)		1.1 (0.9)	1.5 (0.8)	0.8 (0.9)	<0.001
Training (If yes=1; otherwise 0)		284 (64.0)	144 (74.6)	140 (55.8)	<0.001
Social network					
Interaction	1= sometimes	152 (34.2)	43 (22.3)	109 (43.4)	<0.001
	2=occasionally	140 (31.5)	61 (31.6)	79 (31.5)	
	3= very frequently	152 (34.2)	89 (46.1)	63 (25.1)	
Usefulness	1 = not useful,	143 (32.2)	23 (11.9)	120 (47.8)	<0.001
	2=useful	179 (40.3)	92 (47.7)	87 (34.7)	
	3=very useful	122 (27.5)	78 (40.4)	44 (17.5)	
Inputs for production					
Variety (If yes=1; otherwise 0)		273 (61.5)	137 (71.0)	136 (54.2)	<0.001
NPK (kg per ha)		90.7 (71.6)	89.4 (67.4)	91.7 (74.8)	0.734
Seed (kg per ha)		12.9 (9.7)	12.2 (8.2)	13.5 (10.7)	0.161
Human labour (person-days per ha)		66.4 (23.1)	69.5 (22.1)	64.1 (23.6)	0.014
Bullock labour (person-days per ha)		15.5 (7.8)	16.4 (6.2)	14.9 (8.8)	0.038
Farm machine (hours per ha)		14.9 (7.0)	15.9 (5.7)	14.1 (7.8)	0.008
FYM (tonnes per ha)		2.4 (4.0)	2.3 (3.9)	2.4 (4.1)	0.959

Notes #Benefits perception index is constructed using PCA of benefits of soil bunds perceived by the farmers for reduction in soil loss, run-off, and improving groundwater table, soil moisture, and fertility.

Table 2 Group-specific and meta-frontier technical efficiency under variable returns to scale (VRS)

Category	Technical efficiency	Mean	SD	Min	Max
Adopters	GSTE	0.83	0.16	0.39	1.00
	MFTE	0.68	0.16	0.35	0.94
	MTR	0.82	1.00	0.90	0.94
Non-adopters	GSTE	0.84	0.13	0.38	0.97
	MFTE	0.53	0.14	0.28	0.84
	MTR	0.63	1.08	0.74	0.87

Notes: GSTE is group-specific technical score; MFTE is meta-frontier technical score; MTR is meta-technology ratio.

Table 3 Distribution of group-specific and meta-frontier of technical efficiency scores (%)

TE class	Group-specific		Meta-frontier
	Adopters	Non-adopters	All farms
30–40	0.50	0.40	12.70
40–50	3.60	3.20	21.60
50–60	8.30	6.40	18.00
60–70	8.30	6.40	17.30
70–80	13.50	5.20	16.20
80–90	20.20	36.30	9.20
90–100	45.60	42.20	5.00
Total	193(100)	251(100)	444 (100)

The fertility of the soil in the study area is poor, and its carbon content is low (Wani 2011). Larger the number of livestock units, higher the amount of manure; and the application of manure favourably affects soil health and, in turn, the efficiency in sorghum production. The type of soil and the slope of the plot are found to have a negative influence on efficiency. Generally, higher the slope, higher the soil erosion—the top, fertile layer of soil is washed away, reducing the productive capacity and health of the soil (Sharda and Dogra 2013) and, in turn, its efficiency.

The infiltration capacity of black soils is very low in comparison to that of red soils, and the low infiltration capacity frequently leads to waterlogging and cracking and lowers productivity and, thereby, efficiency in sorghum production. The production capacity of fertile soils is greater than that of less fertile soils. Fertile soils conserve soil moisture and these are resilient to drought conditions. Soil fertility is negatively associated with inefficiency; interestingly, though, fertility has an insignificant effect on inefficiency in the plots of non-adopters, because the soil bunds on their plots conserve soil moisture despite the soil being fertile.

Training farmers had a negative effect on inefficiency. Training improves farmers' understanding of the adverse effects of soil erosion and of the benefits of adopting conservation measures and the improved package of practices. Our results are consistent with the findings of earlier studies (Tipi et al. 2009: Majumder et al. 2016).

Access to extension service centres had a positive effect on the efficiency of the plots of adopters and non-adopters. By visiting extension service centers, farmers learn of quality inputs (improved seeds, micronutrients, and fertilizers) and of the improved package of practices that helps improve efficiency. Visits to model watersheds to get real, field-level experience of the effectiveness of conservation measures, or exposure visits, had a favorable influence on efficiency for adopters. The influence on efficiency was insignificant for non-adopters (farmers of untreated areas) because they did not have the opportunity to make an exposure visit.

Impact of NRM technologies on technical inefficiency

The results of the falsification test (Table 5) show the validity of the taken instrumental variables. In the selection model, the 'perceived benefits of soil bunds on reducing the run-off' are significantly positive, as are the 'perceived benefits of soil bunds on enhancing soil moisture', but both variables are insignificant in the non-adopter outcome model, implying that these have no significant effect on efficiency. Therefore, it can be stated that the selected instruments are valid.

Among household-specific features, off-farm income, farm assets, and access to credit are associated

Table 4 Factors affecting group-specific technical inefficiency in sorghum cultivation

Variables	Adopters			Non-adopters		
	Estimates	confidence intervals (alpha 0.05)		Estimates	confidence intervals (alpha 0.05)	
Intercept	5.415**	3.049	11.842	–3.323	–9.318	1.510
Household-level characteristics						
Head	–1.087**	–2.850	–0.422	0.750**	0.070	1.783
Age	–0.087**	–0.173	–0.080	0.018	–0.006	0.052
Education	0.045	–0.039	0.155	0.064**	0.004	0.170
Dependency ratio	–3.402**	–6.682	–3.147	–1.582**	–3.140	–0.943
Livestock	–0.248**	–0.554	–0.153	0.090**	0.017	0.239
Farm asset index	–8.208**	–17.174	–3.494	4.670**	3.737	9.116
Access to credit	–3.280**	–6.385	–3.183	0.632	–0.141	1.633
Farm/plot-level characteristics						
Tenure	0.569	–0.305	1.772	0.419	–0.207	1.214
Plot size	0.030	–0.795	1.072	–0.254	–0.849	0.280
slope of plot	1.882**	1.618	3.875	1.083**	0.017	2.513
Red soil	0.513	–0.838	2.304	0.578	–0.409	1.767
Black soil	2.865**	2.393	5.760	1.513**	0.745	3.120
Soil erosion (high)	0.744	–0.304	2.221	–0.264	–1.134	0.370
Soil erosion (medium)	0.333	–1.088	1.972	0.852**	0.150	2.203
Fertility of plot (high)	–4.822**	–9.972	–4.485	1.787	–1.170	4.104
Fertility of plot (medium)	–2.806**	–6.587	–1.919	1.725	–1.274	4.047
Variety	1.187	0.780	2.713	0.069	–0.656	0.759
Perception of farmers						
Risk perception	0.088	–0.536	0.882	–0.369**	–0.955	–0.017
Benefit perception index	–0.703**	–1.504	–0.511	–0.424**	–0.841	–0.310
Extension and Training services						
Training	–2.071**	–4.205	–1.692	0.369	–0.369	1.199
Visits to KVK and RSK	–0.918**	–0.844	–1.788	–0.186**	–0.461	–0.048
Exposure visits	–0.469**	–0.166	–1.283	–0.020	–0.375	0.395
Regional Dummy						
Tumkur	–0.306	–1.606	0.814	–0.686**	–1.751	–0.111
Bidar	–1.501**	–3.551	–0.798	–0.889**	–2.054	–0.302
Gadag	–3.970**	–7.832	–3.607	–2.280**	–4.365	–1.595
Sigma	1.422	1.471	2.427	1.054	1.012	1.686

Note ** If the confidence interval (measured @5%) is devoid of zero, then the coefficient is significant at 5% level of significance.

Table 5 Falsification test for validity of selected instruments

Instrument variables	Selection model			Non-adopters outcome model		
	Estimate	Std. Error	Pr(>|t|)	Estimate	Std. Error	Pr(>|t|)
Intercept	0.201	0.081	0.013	1.971	0.126	0.000
Perceived benefits of soil bunds on reducing the run-off	0.041	0.017	0.016	–0.015	0.026	0.546
Perceived benefits of soil bunds on enhancing soil moisture	0.033	0.020	0.094	0.031	0.031	0.330
$\chi^2(2)$	4.993		0.007	0.635		0.531
Observations (plots)	444			251		

positively with the adoption of NRM technologies (Table 6). Off-farm income may improve the financial capacity of resource-poor farmers and, thereby, the probability of adoption of NRM technologies (Ervin and Ervin 1982; Lapar and Pandey 1999) or, on the other hand, negatively affect adoption (Pender and Kerr 1998; Shiferaw and Holden 2000; Gebremedhin and Swinton 2003; Tenge, De Graaff, and Hella 2004; Amsalu and De Graaff 2007), as off-farm sources of income might reduce farmers' interest in farming and in investing in conservation measures (Ervin and Ervin, 1982; Bravo-Ureta et al. 2006; Teklewold and Köhlin 2011).

As NRM technologies are capital-intensive, and few farmers in the region have the capacity to invest, access to credit helps them overcome their credit constraints and positively affects adoption. Other researchers (Pattanayak et al. 2003) report similar findings.

The slope of a plot, level of erosion, and tenure have a significant and positive bearing on the take-up of conservation technologies. Slope is one of the important factors influencing soil erosion. Higher the slope, higher the soil loss due to water erosion. The slope of a plot also negatively influences the availability of soil moisture for crop growth. Numerous studies report a positive association of slope with the adoption of NRM technologies (Ervin and Ervin 1982; Shiferaw and Holden 1998; Bekele and Drake 2003; Gebremedhin and Swinton 2003; Amsalu and De Graaff 2007; Dessie, Wurzinger, and Hauser 2012).

The extent of soil erosion, or the loss of productive soil from the field, is another crucial factor determining adoption. Adoption is higher for farmers who perceive that soil erosion is affecting the productivity of their farm negatively (Norris and Batie 1987; Shiferaw and Holden 1998; Willy and Holm-Müller 2013).

The effects of the adoption of NRM technologies are less visible or tangible in the short term than in the long term, and farmers on short-term leases have less incentive to invest. Many studies report a positive relationship between tenure security and the adoption of NRM technologies (Shiferaw and Holden 1998; Teklewold and Köhlin 2011b), similar to our results. We also found that the fertility level negatively affects adoption.

The plots are relatively flat, and the soil depth is sufficient for good crop growth; the marginal benefits, or incremental yield changes, are very low, and farmers do not consider investing in such plots worthwhile. Our results are in line with other studies (Amsalu and De Graaff 2007; Tesfaye et al. 2014).

Training and extension services are associated with a higher likelihood of adoption of NRM technologies—which are knowledge-intensive (Barrett et al. 2002) and require appropriate structural design and location and stability and durability measures—and inadequate technical support is a major reason for low adoption (Bekele and Drake 2003; Dessie et al. 2012). Therefore, and in conformity with earlier studies (Sidibé 2005), proper training is positively associated with adoption of NRM technologies.

Access to extension services informs farmers about NRM technologies that are suitable and available, and of the technical know-how, and it helps farmers understand that soil erosion can potentially reduce production and that it has negative, long-term consequences. We found that visits to Krishi Vigyan Kendras and Raita Samparka Kendras are positively associated with adoption, as reported by many researchers (Mbaga-Semgalawe and Folmer 2000; Adegbola and Gardebroek 2007; Di Falco, Teklewold and Köhlin 2011; Veronesi, and Yesuf 2011; Mugonola et al. 2013; Mango et al. 2017). A high perception of risk is positively associated with adoption, as farmers who perceive that the risk of crop failure is high try to minimize their risk by adopting NRM technologies.

Farmers who interact with others about the benefits of conservation technologies rated such interactions highly useful and they were associated with a higher probability of adoption. Social networks positively influence the chances of the uptake of conservation measures, as expected. Community- or watershed-level efforts are needed to improve adoption; therefore, social networks are critical. Moreover, social networks encourage cooperative behaviour—a prerequisite for conservation programmes to succeed—since the flow of water from plots is interconnected. Our findings tie up well with earlier studies (Krishna 2001; Nyangena 2008; Teshome, Rolker, and de Graaff 2013)

Treatment effects

Counterfactual analysis shows that the ATT is –0.24, or soil bunds can reduce technical inefficiency in sorghum production for adopter farms by around

Table 6 Full information maximum likelihood estimates of endogenous switching regression model

	Selection		Adoption		Non-adoption	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Intercept	–3.785	1.197	0.824	0.466*	0.308	0.129
Household-specific features						
Head	0.491*	0.275	0.003	0.065	0.039	0.029
Age	–0.004	0.008	–0.001	0.002	–0.001	0.001
Education	–0.002	0.023	–0.011*	0.006	0.004	0.002
Dependency ratio	–0.354	0.237	–0.053	0.062	–0.001	0.023
Off'farm income	1.170***	0.215	–0.036**	0.100	–0.023*	0.029
Livestock	–0.003	0.036	0.010	0.010	–0.004*	0.004
Farm asset index	0.176*	0.054	0.274	0.200	0.025	0.093
Access to credit	0.071**	0.212	–0.016*	0.064	–0.070***	0.023
Plot-level features						
slope of plot	1.088***	0.233	0.242**	0.100	0.008*	0.027
Red soil	0.348	0.298	0.011	0.085	0.004	0.031
Black soil	0.234	0.292	0.035	0.082	0.015	0.029
Soil erosion (high)	0.117*	0.055	0.026	0.066	0.013*	0.027
Soil erosion (medium)	–0.380	0.304	0.103	0.082	–0.027	0.031
Fertility of plot (high)	–0.135	0.525	0.178	0.131	–0.022*	0.055
Fertility of plot (medium)	–0.353	0.528	0.179	0.134	0.014	0.053
Tenure	0.285**	0.031	0.007	0.066	–0.015*	0.024
Extension services						
Training	0.353*	0.120	–0.118*	0.068	–0.019	0.022
Visits to KVK and RSK	0.114*	0.061	–0.022	0.019	–0.002	0.007
Risk perception	0.296***	0.079	–0.024	0.021	–0.011	0.011
Social network						
Interaction with other farmers	0.311**	0.120	–0.003	0.039	–0.028*	0.015
Usefulness of interaction	0.636***	0.136	–0.004	0.050	–0.011	0.017
Inputs for production						
Variety	0.211	0.208	–0.105*	0.060	–0.033	0.022
NPK	–0.002	0.001	0.0001	0.004	0.001***	0.0002
SEED	–0.014	0.014	–0.004	0.004	–0.002	0.001
Human labour	0.005	0.005	0.003**	–0.001	0.014***	0.005
Bullock labour	–0.015	0.017	0.010**	–0.004	0.037***	0.002
Farm machine	–0.072***	0.016	0.001	–0.006	0.017***	0.002
FYM	–0.209***	0.050	0.050**	0.016	0.008	0.005
Regional Dummy						
Tukumkur	–0.311	0.275	–0.034	0.072	0.020	0.031
Bidar	–0.209	0.280	–0.014	0.072	–0.091***	0.030
Gadag	–0.362	0.289	–0.105	0.079	–0.014	0.030
Instrument variables@						
PBrunoff	0.067*	0.070				
PBmoisture	0.074	0.088				
sigma			0.160***	0.009	0.333***	0.017
rho			–0.536*	0.305	–0.074	0.445
Joint significance of plot-level characteristics df=15, stat= 29.099 0.01562 *						
Wald test: X2 = 147.1, df = 38, P(> X2) =0.000						

Note PBrunoff indicates the 'perceived benefits of soil bunds on reducing the run-off; PBmoisture indicated the 'perceived benefits of soil bunds on enhancing soil moisture'

Table 7 Treatment effects of natural resource management technology on adopter and non-adopter

Sub-sample	Decision		Treatment Effects	Change (%)
	Adopters	Non-adopters		
Adopters	1.56 (0.24)	1.80 (0.41)	ATT= –0.24*** (0.02)	–13.33
Non-adopters	1.61 (0.25)	2.02 (0.52)	ATU= –0.41*** (0.03)	–20.29
Heterogeneity effects	–0.056 (0.02)	–0.22 (0.04)	ATH= 0.17(0.03)	

Notes: Figures in parentheses are standard errors; *** indicates significance level at 1%.ATT is average treatment effect on treated (adopters)ATU is average treatment effect on untreated (non-adopters)ATH is average treatment heterogeneity

13.33% (Table 7). The ATU indicates that technical inefficiency can be reduced by 20.29% for non-adopter farms.

Conclusions

This study assesses the factors affecting the adoption of NRM technologies—i.e., soil bunds—which are highly recommended in the drought-prone areas of Karnataka. We used the double bootstrap DEA method to estimate the bias-corrected efficiency scores and the meta-frontier approach to compute the MTR. We used the ESR model to control for the heterogeneity effects of observed and unobserved factors.

We observed that the key factors affecting adoption are access to credit, extension services, and social networks; therefore, these factors need to be considered in formulating conservation programmes. We found that the TE of sorghum production may be enhanced by improving access to credit, the perception of the benefits of adopting NRM technologies, training, exposure visits, and extension services.

The observed MTR is 0.82 for adopters and 0.63 for non-adopters, or that shifting from non-adopters to adopters can improve the efficiency of sorghum production by 30%. The results of the ESR show that the ATT is "0.24, or that adopting soil bunds would reduce the inefficiency in sorghum production by around 13%.

Hence, we construe that the adoption of NRM technologies (soil bunds) could be an important strategy to enhance the performance of sorghum production in the drought-prone areas of the semi-arid tropics of India and, thereby, sustain the natural resources and livelihoods of resource-poor farmers.

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References

Abdulai, A, and W Huffman. 2014. The adoption and impact of soil and water conservation technology: an endogenous switching regression application. *Land Economics* 90(1): 26–43.doi 10.3368/le.90.1.26

Adegbola, P, and C Gardebroek. 2007. The effect of information sources on technology adoption and modification decisions. *Agricultural Economics* 37(1): 55–65. doi.org/10.1111/j.1574-0862.2007.00222.x

Alene, A D, and Victor M Manyong. 2007. The effects of education on agricultural productivity under traditional and improved technology in northern nigeria: an endogenous switching regression analysis. *Empirical Economics* 32(1): 141–159. doi.org/10.1007/s00181-006-0076-3

Amsalu, A, and J D Graaff. 2007. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. *Ecological Economics* 61(2–3): 294–302. doi.org/10.1016/j.ecolecon.2006.01.014

Arya, S L, P Panwar, and R P Yadav. 2011. Role of watershed management in bridging demand–supply gap of fodder for enhancing livestock production in Shivaliks, Haryana. *Agricultural Economics Research Review* 24(347-2016–16956): 225–234.

Banker, R D, and R Natarajan. 2008. Evaluating contextual variables affecting productivity using data envelopment analysis. *Operations Research* 56(1): 48–58. doi.org/10.1287/opre.1070.0460

Barrett, C B, F Place, A Aboud, and D R Brown. 2002. The challenge of stimulating adoption of improved natural resource management practices in African agriculture. *Natural Resource Management in African Agriculture* 31: 1–21.

Battese, G E, D S P Rao, and C J O'donnell. 2004. A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies. *Journal of Productivity Analysis* 21(1): 91–103. doi.org/10.1023/B:PROD.0000012454.06094.29

BCCI-K (Bangalore Climate Change Initiative–Karnataka), 2011. Karnataka ClimateChange Action Plan. Final Report. Government of Karnataka, Bengaluru (India). http://moef.gov.in/wp-content/uploads/2017/08/Karnataka.pdf

Bekele, W, and L Drake. 2003. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto Area. *Ecological Economics* 46(3): 437–451. doi.org/10.1016/S0921-8009(03)00166-6

Bhattacharyya, R, B N Ghosh, P K Mishra, B Mandal, Ch Srinivasa Rao, D Sarkar, K Das, K S Anil, M Lalitha, and K MHati. 2015. Soil degradation in India: challenges and potential solutions. *Sustainability* 7(4): 3528–3570. doi.org/10.3390/su7043528

Biradar, N, and K Sridhar. 2009. Consequences of 2003 drought in Karnataka with particular reference to livestock and fodder. *Journal of Human Ecology* 26(2): 123–130.

Biswas, H, A Raizada, S Kumar, D Mandal, S Srinivas, R Hegde, and P K Mishra. 2019. Soil erosion risk mapping for natural resource conservation planning in Karnataka Region, Southern India. *Indian Journal of Soil Conservation* 47(1): 14–20.

Bravo-Ureta, B E, D Solis, H Cocchi, and R E Quiroga. 2006. The impact of soil conservation and output diversification on farm income in central American hillside farming. *Agricultural Economics* 35(3): 267–276. doi.org/10.1111/j.1574-0862.2006.00161.x

Dessie, Y, M Wurzinger, and M Hauser. 2012. The role of social learning for soil conservation: the case of Amba Zuria land management, Ethiopia. *International Journal of Sustainable Development & World Ecology* 19(3): 258–267. doi.org/10.1080/13504509.2011.636082

Di Falco, S, M Veronesi, and M Yesuf. 2011. Does adaptation to climate change provide food security? a micro-perspective from Ethiopia. *American Journal of Agricultural Economics* 93(3): 829–846. https://doc.rero.ch/record/290349/files/aar006.pdf

Ervin, CA, and D E Ervin. 1982. Factors affecting the use of soil conservation practices: hypotheses, evidence, and policy implications. *Land Economics* 58(3): 277–292. doi.org/10.2307/3145937

Gebremedhin, B, and S M Swinton. 2003. Investment in soil conservation in northern Ethiopia: the role of land tenure security and public programs. *Agricultural Economics* 29(1): 69–84. doi.org/10.1111/j.1574-0862.2003.tb00148.x

Gebrernichael, D, J Nyssen, J Poesen, J Deckers, M Haile, G Govers, and J Moeyersons. 2005. Effectiveness of stone bunds in controlling soil erosion on cropland in the Tigray Highlands, Northern Ethiopia. *Soil Use and Management* 21(3): 287–297. doi.org/10.1111/j.1475-2743.2005.tb00401.x

Hayami, Y, and V W Ruttan. 1971. *Agricultural Development: An International Perspective.* Baltimore, Md/London: The Johns Hopkins Press.

Kerr, J M, and N K Sanghi. 1992. *Indigenous Soil and Water Conservation in India's Semi-Arid Tropics*. IIED International Institute for Environment and Development, http://www.ciesin.org/docs/004-198/004-198.html

Krishna, A. 2001. Moving from the stock of social capital to the flow of benefits: the role of agency. *World Development* 29(6): 925–943. doi.org/10.1016/S0305-750X(01)00020-1

Krishnakanth, B N, and B C Nagaraja. 2020. Adaptations to climate variability and agrarian crisis in Kolar district, Karnataka, India. *Nature Environment and Pollution Technology* 19(3): 1279–1285. doi: 10.46488/NEPT.2020.v19i03.044

Kumar, S, D R Singh, A Singh, N P Singh, and G K Jha. 2020. Does adoption of soil and water conservation practice enhance productivity and reduce risk exposure? empirical evidence from semi-arid tropics (SAT), India. *Sustainability* 12(17): 6965. doi.org/10.3390/su12176965

Laha, A. 2013. Technical efficiency in agricultural production and access to credit in West Bengal, India: a stochastic frontier approach. *International Journal of Food and Agricultural Economics (IJFAEC)* 1(1128-2016–92010): 53–62. doi: 10.22004/ag.econ.160094

Lapar, M L A, and S Pandey. 1999. Adoption of soil conservation: the case of the Philippine Uplands. *Agricultural Economics* 21(3): 241–256. doi.org/10.1016/S0169-5150(99)00028-6

Le, V, Xuan-Binh B V, and S Nghiem. 2018. Technical efficiency of small and medium manufacturing firms in Vietnam: a stochastic meta-frontier analysis. *Economic Analysis and Policy* 59: 84–91. doi: 10.1016/j.eap.2018.03.001

Lokshin, M, and Z Sajaia. 2004. Maximum likelihood estimation of endogenous switching regression models. *The Stata Journal* 4(3): 282–289. https://www.stata-journal.com/article.html?article=st0071

Maddala, G S. 1986. *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge University Press.

Majumder, S, B K Bala, F M Arshad, M A Haque, and MA Hossain. 2016. Food security through increasing technical efficiency and reducing postharvest losses of rice production systems in Bangladesh. *Food Security* 8(2): 361–374. doi.org/10.1007/s12571-016-0558-x

Mango, N, C Makate, L Tamene, P Mponela, and G Ndengu. 2017. Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. *International Soil and Water Conservation Research* 5(2): 122–129. doi.org/10.1016/j.iswcr.2017.04.003

Mbaga-Semgalawe, Z, and H Folmer. 2000. Household adoption behaviour of improved soil conservation: the case of the North Pare and West Usambara Mountains of Tanzania. *Land Use Policy* 17(4): 321–336. doi.org/10.1016/S0264-8377(00)00033-8

McDonald, J. 2009. Using least squares and tobit in second stage DEA efficiency analyses. *European Journal of Operational Research* 197(2): 792–798. http://hdl.handle.net/2328/31398

Mishra, P K, M Singh, and G Kumar. 2018. Water management and conservation innovations for doubling farmers' income. http://www.isss-india.org/downloads/Ab2018.pdf

Moreira, V H, and B E Bravo-Ureta. 2010. Technical efficiency and metatechnology ratios for dairy farms in three southern cone countries: a stochastic meta-frontier model. *Journal of Productivity Analysis* 33(1): 33–45. doi: 10.1007/s11123-009-0144-8

Mugonola, B, J Deckers, J Poesen, M Isabirye, and E Mathijs. 2013. Adoption of soil and water conservation technologies in the Rwizi Catchment of South Western Uganda. *International Journal of Agricultural Sustainability* 11(3): 264–281. doi.org/10.1080/14735903.2012.744906

Nagaraja, B C, R K Somashekar, and A Kavitha. 2011. Impact of drought on agriculture: challenges facing poor farmers of Karnataka, South India. *Climate Change and Security, Norway*. https://www.researchgate.net/publication/313402407_Impact_of_Drought_on_Agriculture_challenges_facing_poor_farmers_of_Karnataka_South_India

Narayan, D, H Biswas, and P Kumar. 2019. Efficacy of contour bunds and vegetative barriers in resource conservation on sloping agricultural land in Bundelkhand Region. *Indian Journal of Soil Conservation* 47(3): 280–285.

Naveena, K P, S Shivaraj, and G P Nithin. 2019. Food security and income stability with soil and water conservation practice in Hebburu Sub-Watershed Tumkur, Karnataka. *Journal of Krishi Vigyan* 7(2): 125–130.

Norris, P E, and S S Batie. 1987. Virginia farmers' soil conservation decisions: an application of tobit analysis. *Journal of Agricultural and Applied Economics* 19(1): 79–90. doi.org/10.1017/S0081305200017404

Nyangena, W. 2008. Social determinants of soil and water conservation in rural Kenya. *Environment, Development and Sustainability* 10(6): 745–767. doi.org/10.1007/s10668-007-9083-6

O'Donnell, C J, D S P Rao, and G E Battese. 2008. Metafrontier frameworks for the study of firm-level efficiencies and technology ratios. *Empirical Economics* 34(2): 231–255. doi.org/10.1007/s00181-007-0119-4

Pathak, P, K B Laryea, and S Singh. 1989. A modified contour bunding system for alfisols of the semi-arid tropics. *Agricultural Water Management* 16(3): 187–199. doi.org/10.1016/0378-3774(89)90002-4

Pattanayak, S K, D E Mercer, E Sills, and J Yang. 2003. Taking stock of agroforestry adoption studies. *Agroforestry Systems* 57(3): 173–186. doi.org/10.1023/A:1024809108210

Pender, J L, and J M Kerr. 1998. Determinants of farmers' indigenous soil and water conservation investments in semi-arid India. *Agricultural Economics* 19(1–2): 113–125. doi.org/10.1016/S0169-5150(98)00026-7

Rajkumar, R H, and U Satishkumar. 2014. Effect of soil and water conservation measures (field bunds) on soil moisture content in Beeralagudda micro watershed. *Asian Journal of Soil Science* 9(1):149–151.

Reddy, B V C, D Hoag, and B S Shobha. 2004. Economic incentives for soil conservation in India. in *Proceedings of the 13th International Soil Conservation Organization Conference, Brisbane*. https://www.tucson.ars.ag.gov/isco/isco13/PAPERS%20R-Z/C%20REDDY.pdf

Sharda, V N, and P Dogra. 2013. Assessment of productivity and monetary losses due to water erosion in rainfed crops across different states of India for prioritization and conservation planning. *Agricultural Research* 2(4): 382–392. doi.org/10.1007/s40003-013-0087-1

Sharma, A, and M B Guled. 2012. Effect of set-furrow method of cultivation in pigeonpea+ greengram intercropping system in medium deep black soil under rainfed conditions. *Karnataka Journal of Agricultural Sciences* 25(1): 18–24.

Shiferaw, B, and S T Holden. 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: a case study in Andit Tid, North Shewa. *Agricultural Economics* 18(3): 233–247. doi.org/10.1016/S0169-5150(98)00036-X

Shiferaw, B, and S T Holden. 2000. Policy instruments for sustainable land management: the case of highland smallholders in Ethiopia. *Agricultural Economics* 22(3): 217–232. doi.org/10.1016/S0169-5150(00)00046-3

Sidibé, A. 2005. Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. *Agricultural Water Management* 71(3): 211–224. doi.org/10.1016/j.agwat.2004.09.002

Simar, L, and P W Wilson. 2007. Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics* 136(1): 31–64. doi.org/10.1016/j.jeconom.2005.07.009

Simar, L, and P W Wilson. 2011. Two-stage DEA: caveat emptor. *Journal of Productivity Analysis* 36(2): 205. doi.org/10.1007/s11123-011-0230-6

Teklewold, H, and G Köhlin. 2011. Risk preferences as determinants of soil conservation decisions in Ethiopia. *Journal of Soil and Water Conservation* 66(2): 87–96. doi.org/10.2489/jswc.66.2.87

Tenge, A J, J D Graaff, and J P Hella. 2004. Social and economic factors affecting the adoption of soil and water conservation in west Usambara highlands, Tanzania. *Land Degradation & Development* 15(2): 99–114. doi.org/10.1002/ldr.606

Tesfaye, A, W Negatu, R Brouwer, and P V der Zaag. 2014. Understanding soil conservation decision of farmers in the Gedeb Watershed, Ethiopia. *Land Degradation & Development* 25(1): 71–79. doi.org/10.1002/ldr.2187

TERI. 2018. Economics of Desertification, Land Degradation and Drought in India Vol I: Macroeconomic Assessment of the Costs of Land Degradation in India The Energy and Resources Institute, 2018, New Delhi, India. https://www.teriin.org/sites/default/files/2018-04/Vol%20I%20-%20Macroeconomic%20assessment%20of%20the%20costs%20of%20land%20degradation%20in%20India_0.pdf

Teshome, A, D Rolker, and J de Graaff. 2013. Financial Viability of soil and water conservation technologies in northwestern Ethiopian highlands. *Applied Geography* 37:139–149. doi.org/10.1016/j.apgeog.2012.11.007

Tipi, T, N Yildiz, M Nargeleçekenler, and B Çetin. 2009. Measuring the technical efficiency and determinants of efficiency of rice (*Oryza Sativa*) farms in Marmara Region, Turkey. *New Zealand Journal of Crop and Horticultural Science* 37(2):121–129. doi.org/10.1080/01140670909510257

Vittal, K P R, P K Sinha, G R Chary, GRM Sankar, T Srijaya, Y S Ramakrishna, J S Samra, and G Singh. 2004. Districtwise Promising Technologies for Rainfed Rice Based Production System in India.*All India Co-Ordinated Research Project for Dryland Agriculture, Central Research Institute for Dryland Agriculture, Indian Council of Agricultural Research, Hyderabad* 500:059. https://www.researchgate.net/publication/325779866_Districtwise_Promising_Technologies_for_Rainfed_Rice_based_Production_System_in_India

Vortia, P, M Nasrin, S K Bipasha, and Md M Islam. 2019. Extent of farm mechanization and technical efficiency of rice production in some selected areas of Bangladesh. *GeoJournal* 1–14. doi.org/10.1007/s10708-019-10095-1

Wani, S P, K L Sahrawat, K V Sarvesh, M Baburao, and K Krishnappa. 2011. *Soil Fertility Atlas for Karnataka, India*. International Crops Research Institute for the Semi-Arid Tropics. http://oar.icrisat.org/6297/

Willy, D K, and K Holm-Müller. 2013. Social influence and collective action effects on farm level soil conservation effort in rural Kenya. *Ecological Economics* 90: 94–103. doi.org/10.1016/j.ecolecon.2013.03.008

Wolka, K, J Mulder, and B Biazin. 2018. Effects of soil and water conservation techniques on crop yield, runoff and soil loss in sub-Saharan Africa: A Review. *Agricultural Water Management* 207:67–79. doi: 10.1016/j.agwat.2018.05.016.

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Production efficiency and profitability of major farming systems in Tamil Nadu

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Abstract This study evaluates the performance of the predominant farming systems in Tamil Nadu using primary data from 192 farmers for 2015–16, and the standard cost and stochastic frontier production function methods. Seven different predominant farming systems were identified, of which the fruits and turmeric farming systems were profitable. The marginal and small farms were more diversified, whereas the large farms were specialized, with high-value crops. The productivity in all the farming systems can be enhanced up to 40% by adopting technologies such as the System of Rice Intensification (SRI), Sustainable Sugarcane Initiative (SSI), and fertigation.

Keywords Farming systems, economic characterization, technical efficiency, crop diversification, agricultural technologies, stochastic frontier production function

JEL codes C21; O12; Q12; Q16; Q18

In 1950–51 India produced 51 million tonnes (mt) of food grains from 97 million hectares (mha); in 2014–15 it produced 254 mt from 123 mha. This increase of 400%, with only 23% increase in gross cultivated area (Economic Survey 2014–15), is a paradigm shift. This shift was enabled the development of high-yielding varieties and the use of improved crop production technologies. The cereals-based cropping systems (rice–wheat, rice–rice, and maize/pearl millet–wheat, etc.) contributed predominantly to the national food basket (IIFSR 2013–14), and intensive farming was vital in improving the cropping intensity in irrigated and rainfed areas and, therefore, increasing food production.

However, in Asia, undernourishment has been estimated to be 12.7% (FAO 2014), and, in India, the requirement of food grains in 2020 has been estimated to be 22% more than the demand (Kumar et al. 2009). To meet this demand the production of food grains needs to increase every year. But productive land has been diverted from agriculture use to infrastructural development, urbanization, and other related activities. The per capita availability of land declined from 0.5 ha in 1950–51 to 0.15 ha by the end of the 20th century, and the availability is projected to decline to less than 0.1 ha in 2020 (Department of Land Resources, GoI 2013). The net cultivated area has hovered between 140–142 mha, and there is almost no possibility of increasing the area under cultivation. In 1995–96, the cropping intensity of the country was 131.2%; it needs to be improved to 150% to meet the food requirement (Pal 2008).

The demand for feed and fodder for the livestock population is increasing, and the sustainability and profitability of farming is seriously challenged by resource degradation, climate change, new pests and diseases, slow growth in farm income, the changing dietary patterns of the population, and export–import policies. Therefore, research and development (R&D) work is needed to develop and implement appropriate strategies and new agricultural technologies that improve farm productivity, profitability, food production and sustain food security.

The farming systems approach is a holistic approach; it boosts crop productivity and profitability sustainably, and it can meet the future food demand without impairing the ecological and environmental balance. No single farm enterprise is likely to generate adequate income and gainful employment for small and marginal farmers year-round; they must adopt integrated farming systems (Mahapatra 1994). Mixed enterprises in the farming system improve the stability of farm income, supply fodder, protect against risks and uncertainty, and help to maintain soil fertility (Sharma and Sharma 2004). Farming systems research, conducted in a holistic manner so that small and marginal farmers can manage their resources (Jha 2003), by integrating various farm enterprises and recycling crop residues and by-products within the farm itself, is imperative to improve productivity, income, and employment (Behera and Mahapatra 1999).

The present investigation is undertaken to identify and characterize the predominant farming systems, estimate their costs and returns, and measure their technical efficiency.

Data, methodology, study area, and sampling

We collected the data, following the guidelines of Indian Agricultural Statistical Research Institute, using a multistage random sample survey method (Sukhatme et al. 1984). We selected the western zone of Tamil Nadu due to its importance in the variations in cropping pattern and agricultural productivity. We selected two districts, Coimbatore and Erode, based on variations in agricultural productivity, at the first stage. Subsequently, we randomly selected two blocks from each district and four villages from each block.

We developed a structured interview schedule based on an extensive literature survey (Dixon et al. 2001), initial case explorations in the field, and expert counsel. We collected data on the socio-economic parameters of households, farm size, infrastructural facilities, farm outputs, value of outputs, prices of outputs received by the farmers, and costs and benefits incurred in farming. Thus, we used the personal interview method to collect data from 192 sample households pertaining to the year 2015–16.

Herfindahl Index

The Herfindahl Index is used to explain either concentration or diversification of crop production activities in a given time and space (Hackbart et al. 1975; De and Chattopadhyay 2010). The Herfindahl Index is one of the criteria used to characterize farming systems, and it is used to measure crop diversification across farming systems in a study area.

$$HI = \sum_{i=1}^{n} P_i^2$$

where n is the total number of crops and P_i represents area proportion of the i^{th} crop in total cropped area.

If diversification increases, the value of the Herfindahl Index decreases. When the concentration is complete, the value of the Index is 1; its value approaches 0 when diversification is 'perfect'. Thus, the Herfindahl Index is bounded by 0 and 1. The value of the Herfindahl Index approaches 0 as 'n' becomes large and assumes 1 when only one crop is cultivated.

Cost and returns analysis

To estimate the profitability of farming systems, we used the standard methodology (CACP 1990) to work out the cost of variable inputs (such as wages, seeds, fertilizers, plant protection, and irrigation) and of fixed inputs (such as the rental value of land, land revenue, and the interest and depreciation on farm buildings and implements).

Stochastic frontier production function approach

The production function represents the maximum possible output for any given set of inputs; it sets a limit, or frontier, on the observed values of a dependent variable. If a farm deviates from the frontier, it is unable to produce the maximum output from its given sets of inputs; the deviation represents the degree of technical inefficiency. A one-sided component captures the measure of inefficiency relative to the stochastic frontier.

The stochastic frontier production function is defined as

$Y_i = f(X_{ki}; \beta_i)\exp(\in_i); \qquad i = 1, \ldots, n;$

where, Y_i is the output of the i^{th} farm; X_{ki} is vector of k inputs of the i^{th} farm; β is vector of parameters; $\in_i$ is the farm-specific error term. This stochastic frontier is also called a 'composed error' model because the error term is composed of two independent elements:

$\in_i = u_i + v_i; \qquad i = 1, \ldots, n$

where v_i is the symmetric component; it represents the statistical 'white noise' and it follows the assumptions of the spherical error term. A one-sided component ($u_i < 0$) reflects the technical efficiency relative to the stochastic frontier, $f(X_i; \beta)e^{vi}$. Thus, $u_i = 0$ for any farm's output lying on the frontier; it is strictly negative for any output lying below the frontier, representing the amount by which the frontier exceeds the actual output on farm 'i'. Assume that it is identically and independently distributed as $N(0, \sigma_u^2)$, that is, the distribution of u is half normal. Battese and Corra (1977) define g as the total variation in output from the frontier, which is attributable to technical inefficiency, that is, $\gamma = \sigma^2_u$ per σ^2, and so $0 < \gamma < 1$. An estimate of γ can be obtained from the estimates of σ^2 and λ. The empirical model used in the present study is specified in the Cobb–Douglas production function (Saravanakumar and Jain 2008):

$Y = \alpha X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} X_7^{\beta_7} X_8^{\beta_8} \in$

Y= yield (kg);

X_1= farm size (acre);

X_2 = seed (INR);

X_3= labour (INR);

X_4 = fertilizer (INR);

X_5 = pesticides (INR);

X_6 = machinery (INR);

X_7 = animal size (number);

X_8 = livestock maintenance (INR);

β_1 to β_8 are coefficients; and

∈ = composed error term.

Results and discussion

The source or enterprise (crops or livestock) from which farmers earned the maximum net income was identified as the predominant farming system (Singh et al. 2008; Goswami et al. 2012; Prasad et al. 2012). Accordingly, seven predominant farming systems were identified in the study area (Figure 1): cereals-based farming (27% of the farmers), oilseed (coconut, 20%), sugarcane (16%), fruits (11%), livestock (11%), vegetable (8%), and turmeric (7%).

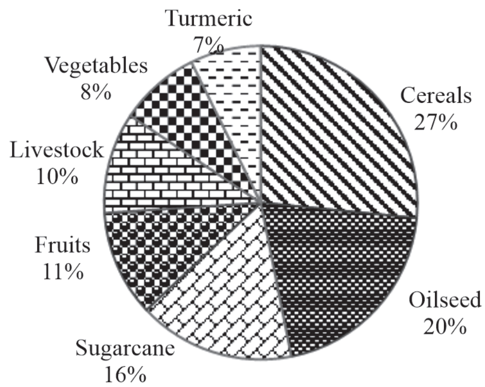

Figure 1 Predominant farming systems

The distribution of farming systems by farm category (Figure 2) indicates that marginal and small farmers widely adopted subsistence farming (cereals, livestock, and sugarcane), while medium and large farmers practised commercial farming (coconut, fruits, and turmeric crops). All farmers rear livestock, but 6.35% of the marginal farmers and 3.65% of the small farmers practise a predominantly livestock-based farming system.

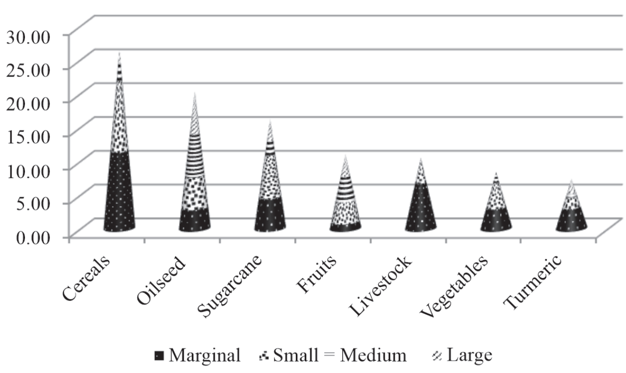

Figure 2 Predominant farming systems by category

Socio-economic characteristics of farming systems

The socio-economic characteristics of the sample households are presented by farming system (Table 1). Each household averaged four members (two adults

Table 1 Socio-economic characteristics of sample households (Tamil Nadu, western zone)

Particulars	Cereal	Livestock	Coconut	Sugarcane	Turmeric	Fruits	Vegetables
Sample size (number)	51	20	39	31	14	21	16
Family size (number)	3.40	4.56	4.50	4.21	4.15	4.10	3.56
Age (in years)	49	53	47	49	47	49	49
Educational index*	3.21	3.67	5.64	3.81	3.92	4.81	4.41
Family labour (number)	1.60	2.38	1.10	1.64	2.08	1.55	1.75
Farm size (ha)	2.92	0.87	3.65	2.88	1.78	3.09	2.42
Herd size (number per ha)	2.33	5.64	2.14	2.61	2.53	1.89	2.17

*Weighted average of formal education received by the household members (illiterate = 0, primary = 1, middle = 2, secondary = 3, higher secondary = 4, graduate = 5 and postgraduate = 6).

and two children). The farmer's age, a proxy for farm experience, ranged from 47 years (turmeric) to 53 years (livestock). The educational index, which exhibits the literacy and knowledge level of farmers in the various farm-related decision-making processes, influences farm efficiency directly and positively. Most of the members of farm households are educated up to the middle or high school level. Livestock farms hold the minimum land, 0.87 ha, and coconut farmers hold the maximum land, 3.65 ha. Livestock-rearing is an integral part of most farming systems. In the fruits-based farming system, 0–3 animals are reared, and the average is 1.89, and up to 7 animals are reared in the livestock-based farming system.

Analysis of cropping pattern

In the western zone of Tamil Nadu, the net cultivated area under cereals, sugarcane, and coconut was about 50% of the total cropped area. In the cereals-based farming system, the maximum area (42.75%) was allocated to cereals, and the rest to pulses cultivation under rice fallow lands, oilseed crops (coconut, groundnut, and sesame), and vegetables. Rice, cultivated by 58% of the farms, was the predominant crop within cereals; 29% of the farmers cultivated maize and 13% cultivated sorghum and minor millets. Most farms in the livestock-based farming system cultivated cereals and pulse crops for the purpose of by-products; 20% of the area was allocated to sorghum fodder and cumbu napier (CN) grass.

In coconut farming, the area allocated to coconut was around 50%; 17% of the area was allocated to vegetables, 7% to fodder, and a meagre portion to fruits and tree crops. Under the sugarcane-based farming system, 52% of the total area was allocated to sugarcane, 11% to oilseed crops such as groundnut and gingelly, 10% to turmeric, and 9% to cereals. Under the fruits-based farming system, 46% of the area was occupied by fruit crops such as banana (G-9, Nendran), banana leaf, and mango, followed by coconut, cereals, pulses, and vegetable crops.

The major crops grown by farmers in the vegetable farming system were bhendi, tomato, brinjal, cauliflower, lablab, cabbage, and onion; cereals, turmeric, coconut, and pulses were also cultivated. In the turmeric farming system, the area allocated for turmeric crop ranged from 31.40% (marginal farms) to 69.10% (large farms), along with onion and chilli as intercrops.

Crop diversification

The Herfindahl Index measures the degree of crop diversification at the farm level based on the number of crops or enterprises undertaken in the net cropped area. Figure 3 presents the degree of diversification by farm category and farming system.

The values of the Herfindahl Index ranged from 0.23 for marginal farms under the cereals-based farming system to 0.36 for small farms under the fruits-based farming system; the degree of diversification was higher in cereals-based farms. Small and marginal farms diversified with horticultural crops, indicating that farmers were shifting from low-value crops to high-value crops. This finding is in line with Velavan and Balaji (2012), which also finds that crop diversification took place in Tamil Nadu from 1960 to 2007. The diversification towards cash crops such as cotton and

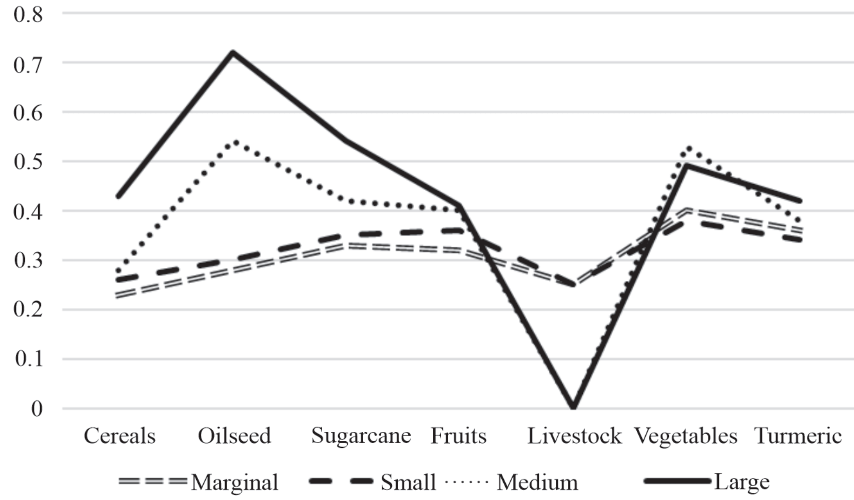

Figure 3 Crop diversification by farming system

sugarcane was significant (Mukherjee 2010), though the rice- and wheat-based cropping systems prevailed during these decades across India.

Under the coconut, sugarcane, and vegetables farming systems among large farms, the values of the Herfindahl Index ranged from 0.50 to 0.72 (nearer to 1), because the inadequate supply of family labour necessitated greater use of farm machinery and capital inputs and tenant farming, and it implies that the degree of specialization with these crops at the level of large farming systems is high. Farm size has a negative relationship with the degree of diversification, that is, marginal and small farms were more diversified than medium or large farms (Mehta 2009).

Employment generation in different farming systems

The patterns and magnitude of total human labour employed per hectare for various crops under different farming systems are presented in Table 2. The highest farm employment was estimated to be 426 person-days per hectare per annum in sugarcane-based farming system, followed by turmeric (406 person-days), vegetables (316 person-days), fruits (279 person-days), coconut (208 person-days), cereals (206 person-days), and livestock (121 person-days). Sugarcane and turmeric are labour-intensive crops, and these require more labour for de-trashing, harvesting, special agronomic practices, and processing operations (Saravanakumar et al. 2012). Drip irrigation and fertigation are used in coconut and fruits farming, and farming is seasonal; therefore, less labour is required.

Cost of crop production in different farming systems

The total cost of crop production was calculated (Table 3). Overall, the total cost incurred by the sugarcane farming system is INR 101,895 per ha. Small farmers incurred a higher cost (INR 109,289 per ha) than other categories, indicating that in this system resource

Table 2 Employment generation (person-days / ha / annum)

Farming system	Marginal	Small	Medium	Large	Overall
Cereal	204	201	215	221	210
Livestock	127	108	-	-	121
Turmeric	446	388	384	259	406
Coconut	210	212	194	212	208
Sugarcane	433	432	419	419	426
Vegetables	320	359	255	251	316
Fruits	-	306	287	222	279

Table 3 Input cost of crop production (Tamil Nadu, western zone)

(INR / ha / year)

Farming system	Marginal	Small	Medium	Large	Total
Cereal	39,685	46,548	49,596	49,707	46,283
Livestock	38,169	34555	-	-	36865
Turmeric	89,490	86,141	84,154	85,990	86,444
Coconut	49,602	49,818	47,232	46,233	48,221
Sugarcane	101,987	109,289	95,257	101,046	101,895
Vegetables	69,874	75,393	73,938	78,577	77,494
Fruits	-	90539	89,415	89,386	89,780

allocation was most efficient in large farms. Overall, the total cost incurred was INR 46,283 per ha by the cereals-based farming system; INR 36,865 per ha by the livestock system, lower than the other farming systems; INR 77,494 per ha by the vegetables system, and INR 89,780 per ha by the fruits system.

In the turmeric-based farming system, the average cost was worked out to be INR 86,444 per ha, of which the major proportion was incurred for human labour (INR 47,913 per ha), fertilizer (INR 10,005 per ha), rhizome (INR 9,529 per ha), plant protection (INR 6,260 per ha), machine labour (INR 6,135 per ha), irrigation (INR 4,179 per ha), and transport (INR 2,425 per ha). Cereals- and livestock-based systems incurred the lowest cost overall as small and marginal holders labour on their farms and depend less on markets.

The percentage share of the various input costs (Figure 4) shows that the labour cost of fruits and vegetables production is huge: 47% for the fruits system and 59% for the vegetables system. The government should make available the appropriate capital-intensive techniques (machinery to plant sugarcane stems, weeders, and harvesting machines) on a subsidy or custom-hiring basis. The cost of seeds accounted for a share of 9%–25%, the second-largest share, in various farming systems. The percentage share of machine labour cost or custom hiring charges to total cost was high in sugarcane and cereal farms (14%). The other input costs (fertilizer, irrigation, and transportation) accounted for 20%–25% of the total cost, the remaining share.

Profitability in different farming systems

The net farm income, a measure of crop productivity and farm profitability, served as the criterion for identifying the predominant farming systems. The net farm income per hectare per annum for different farm enterprises is given in Figure 5. The income was INR 255,432 per annum for fruits-based farming, the highest, and INR 231,036 per annum for turmeric, INR

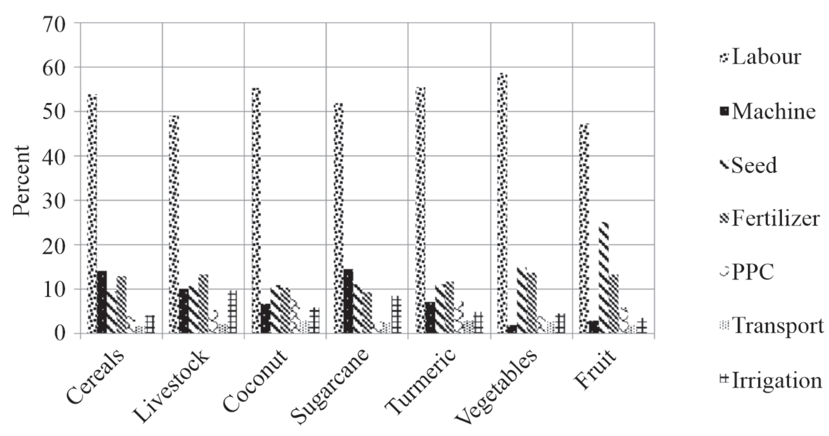

Figure 4 Share of inputs cost to total cost by farming system

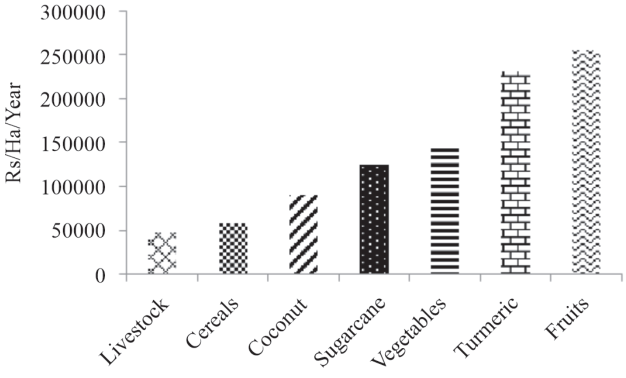

Figure 5 Net income earned per month by farming system

146,460 per annum for vegetables, INR 124,060 per annum for sugarcane, INR 90,300 per annum for coconut, INR 58,752 per annum for cereals, and INR 47,676 per annum for livestock. The profitability of the cereals and livestock farming systems was less for the other farming systems. From 1960 to 2007, the profitability of rice and sugarcane crops decreased, and farmers realized a loss for some years (Narayanamoorthy 2013).

Technical efficiency across different farming systems

The efficiency of the farms was estimated by the stochastic frontier maximum likelihood estimation technique (Table 4). The value of the estimate of log likelihood ratio was significantly different from 0, which followed chi-square distribution, indicating the 'goodness of fit' of the model. The impact of farm size was positive and significant for coconut, sugarcane, and livestock farms. A one-hectare increase in farm size would increase output by 0.13% for coconut, 0.36% for sugarcane, and 0.08% for livestock. Seeds significantly influence output; a one-percent increase in expenditure on seed is expected to raise the output of cereals by 0.13%, sugarcane by 0.07%, and the output of turmeric by 0.11%.

Fertilizer significantly affects the output of all crops, coconut and turmeric are more responsive than cereals or sugarcane to an additional level of fertilizer. Machine power was significant for only the sugarcane crop; its elasticity, 0.21%, indicates that a 10% increase in the machinery level is expected to increase the sugarcane output by 2.1%. The milk output of livestock farms

Table 4 Maximum likelihood estimates

Variable	Cereals	Coconut	Sugarcane	Turmeric	Livestock
Constant	4.2465***	0.9159	6.9088***	1.7916	2.3336***
	(0.8301)	(0.7822)	(0.8804)	(0.3389)	(0.3386)
Farm size	-0.2502	0.1338*	0.3900 ***	0.04385	0.0756*
	(0.0768)	(0.0765)	(0.0932)	(0.0407)	(0.0553)
Seed	0.1341**	0.1169	0.0796*	0.1194***	-0.0197
	(0.0684)	(0.0417)	(0.0494)	(0.0562)	(0.0185)
Labour	0.4623	0.1939***	0.1913	0.0811	0.3094***
	(0.1489)	(0.0724)	(0.1035)	(0.0832)	(0.0769)
Fertilizer	0.0710*	0.2283***	0.0529*	0.2725***	0.0191
	(0.0792)	(0.0496)	(0.0502)	(0.0844)	(0.0622)
Pesticide	0.0281	0.0043	-0.0011	0.0632	-
	(0.0842)	(0.0463)	(0.0357)	(0.0451)	
Machinery	0.0471	0.0315	0.2140**	0.2220	-0.0084
	(0.0824)	(0.0535)	(0.0741)	(0.0617)	(0.0399)
Animal size	-	-	-	-	0.1441***
					(0.0533)
Livestock maintenance cost	-	-	-	-	0.2632***
					(0.3386)
γ	0.7789***	0.8365***	0.8005*	0.7931**	0.8461**
LLF	-54.14	-40.399	17.69	55.67	46.38
N	87	96	39	52	124

(***P<0.01, **P<0.05, *P<0.1)

was determined primarily by labour, animal size, and the cost of livestock maintenance.

The variance parameter g was positive and significant. The value of γ was 0.7789 for cereals, implying that about 77% of the differences in farm productivity were due to farm-specific practices. The value of γ was 0.8365 for coconut, 0.8005 for sugarcane, 0.7931 for turmeric, and 0.8461 for livestock. Therefore, farm-specific variability contributed, respectively, 83%, 80%, 79%, and 84% of the differences in the farm productivity of coconut, sugarcane, turmeric, and livestock; the rest was due to random error, and the total variation in production from the frontier was attributable to technical inefficiency. Therefore, farm productivity can be enhanced by improving farm-specific practices, which farmers control.

Farm-specific technical efficiencies

The farm-specific technical efficiencies under different farming systems and their frequency distribution are estimated and presented in Table 5. The technical efficiency of cereals farms ranged from 64% to 93%; its average, 0.7928, implies that cereals farms realize only 79% of their technical ability. Approximately 26% of cereals farms realized more than 90% of its output, but 74% lost up to 40% (90%<TE>60%) under the existing technology. There is scope for improvement in crop output and, thereby, farm profitability across different farming systems. Specialized farms (coconut farms) were more efficient than diversified farms (cereals farms).

Potential yield improvements

Based on the technical efficiency of the most efficient farm, following the practices of the most efficient farmer can help the average cereals farmer in the sample improve productivity by 16.81%. Improving technical efficiency can increase the average potential for production by 8.92% for coconut, 13.01% for sugarcane, 13.75% for turmeric, and by 13.48% for livestock. This result is in line with Saravanakumar and Jain (2008), which find the technical efficiency to vary from 57% to 100%.

The most efficient farms and their farm-specific practices based on their technical efficiency scores are detailed in Table 6. Following the practices of the most efficient farms can help the average farms enhance productivity; cereals farms can improve productivity by 16.81%, coconut farms by 22.42%, sugarcane farms by 19.01%, turmeric farms by 13.75%, and milk farms by 17.28%.

The most efficient rice farmers adopted components of the System of Rice Intensification (SRI) like line sowing, and they used the Cono Weeder. To extend the crop life, they sprayed pink-pigmented facultative methylotrophs (PPFM) Methylobacterium during conditions of water stress. The most efficient coconut farmers practised drip irrigation for effective water use and fertigation; to harvest the maximum yield of 20,034 nuts per year, they applied micronutrient mixture (MNM) tonic, 50 g of vesicular arbuscular mycorrhizae (VAM), and 100 g of Azophos once in six months.

Table 5 Frequency distribution of technical efficiency (%)

Efficiency level (%)	Cereals	Coconut	Sugarcane	Turmeric	Livestock
90–99 %	26.44	46.88	30.77	21.15	33.87
80–89 %	41.38	38.54	43.59	50.00	55.65
70–79 %	21.84	14.58	20.51	28.85	10.48
60–69 %	10.34	0.00	5.13	0.00	0.00
Total (%)	100.00	100.00	100.00	100.00	100.00
N (No. of farms)	87	96	39	52	124
Mean technical efficiency (%)	0.7928	0.8825	0.8165	0.8225	0.8526
Standard deviation	0.0963	0.0927	0.1217	0.0772	0.0973
Maximum technical efficiency (%)	0.9261	0.9612	0.9227	0.9356	0.9675
Minimum technical efficiency (%)	0.6355	0.7824	0.6925	0.7345	0.7930

Table 6 Productivity enhancement potential

Crop	Average farmyield	Most efficientyield	Productivity increase (%)
Rice (kg)	4,525	5,285	16.81
Coconut (nuts)	16,500	20,034	21.42
Sugarcane (tonnes)	102	122	19.01
Turmeric (kg)	5,380	6,119	13.75
Milk (litre)	9.2	10.49	17.28

The most efficient sugarcane farmers adopted the Sustainable Sugarcane Initiative (SSI) method, and they applied MNM tonic, humic acid, and liquid biofertilizers like Azotobacter (AzoPro) and Phosphate Solubilizing biofertilizer (PhoSol) to attain the maximum yield of 122 tonnes per hectare. The most efficient turmeric farmers in the western zone also practised drip irrigation and fertigation, and periodically applied borax micronutrient mixture. The most efficient dairy farmers practised balanced feeding and properly managed animal health.

Conclusions

Farmers are shifting from low-value cropping systems to high-income generating systems—such as fruits, vegetables, and coconut. This result is in line with those of Mehta (2009) and Mukherjee (2010), which also find that farmers switch to horticultural or high-value crops because their productivity and income are higher.

The Herfindahl Index of crop diversification shows that to avoid risk, marginal and small farmers tend to diversify their cropping pattern with horticultural and high-value crops. The range varied widely by farmer size class, indicating that diversification is greater among marginal and small farmers, and specialization is greater among large farms.

Farms that grow fruits and vegetables generate greater profits than those that grow rice and other subsistence crops such as cereals and pulses. Predominantly marginal and small farms adopt livestock, but these are maintained by all categories of farms. Farming systems based on livestock and cereals utilize by-products and family labour effectively, and their cost of milk production is the lowest.

Our technical efficiency estimates of all the farming systems indicate that their productivity can be enhanced up to 40%; thereby, farm profits can improve, too. Farm productivity can be improved by the widespread adoption of recently developed resource-efficient, productivity-enhancing technologies, like SRI and direct sowing for cereal farms, and SSI among sugarcane farmers. Therefore, farmers should be educated periodically on the latest farming tools, techniques, and technologies—such as drip irrigation, fertigation, raising intercrops, MNM, and biofertilizer use—by agricultural extension services officers through method and result demonstrations, field visits, and training. Farmers need to be encouraged to adopt high-value, low-volume crops such as medicinal and aromatic plants, and also high-productive dairy animals and poultry.

Adopting income stabilization measures, like effective input management strategies, can improve farm productivity. Employment under the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) is deployed to meet the demand for agricultural labour in the peak season; this policy should be continued. The labour cost is huge, and the government should make the appropriate capital-intensive tools available on a subsidy or custom-hiring basis.

The main contribution of this study was to examine the profitability, employment generation, and technical efficiency of different cropping systems rather than on a single enterprise basis. Emphasis has been increasing on doubling farmers' income and ensuring zero hunger. In this contemporary agricultural policy context, farming systems have greater potential than single enterprises to mitigate agricultural production risks, improve profitability, utilize resources, and generate income sustainably. To help policymakers understand the productive efficiency and profitability of agricultural production systems from a holistic perspective, the economic analysis of agricultural production should be undertaken from the perspective of farming systems rather than of an individual enterprise.

References

Battese, G E, and G S Corra. 1977. Estimation of a production frontier model: With application to the pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics* 21(3): 169–179. https://doi.org/10.1111/j.1467-8489.1977.tb00204.x

Behera, U K, and I C Mahapatra. 1999. Income and employment generation of small and marginal farmers through integrated farming systems. *Indian Journal of Agronomy* 44(3): 431–439.

Commission on Agricultural Cost and Prices (CACP). 1990. Report of the Expert Committee for Review of Methodology of Cost of Production of Crops. Ministry of Agriculture, Government of India New Delhi.

De, U K, and M Chattopadhyay. 2010. Crop diversification by poor peasants and role of infrastructure: Evidence from West Bengal. *Journal of Development and Agricultural Economics* 2(10): 340–350.

Department of Economic Affairs Economic Division. 2015. Economic Survey 2014–15 , Ministry of Finance, Government of India New Delhi. https://www.indiabudget.gov.in/budget2015-2016/es2014-15/echapter-vol1.pdf

Department of Land Resources, Ministry of Rural Development, Government of India 2013. National Land Utilisation Policy Framework for land use planning & management. Draft Report, New Delhi. https://smartnet.niua.org/sites/default/files/resources/draft_national_land_utilisation_policy_july_2013.pdf

Dixon, J, A Gulliver, and D Gibbon. 2001. Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World, FAO, Rome.

FAO, IFAD, and WFP. 2014. The state of food insecurity in the World 2014- Strengthening the enabling environment for food security and nutrition, Rome, FAO. http://www.fao.org/3/a-i4030e.pdf

Goswami, R, M S Biswas, and D Basu. 2012. Validation of participatory farming situation identification: a case of rainfed rice cultivation in selected area of West Bengal, India. *Indian Journal of Traditional Knowledge* 11: 471–479.

Hackbart, M, and D A Anderson. 1975. On measuring economic diversification. *Land Economics* 51(4), 374–378. DOI: 10.2307/3144954

Indian Institute of Farming Systems Research (IIFSR), Modipuram, Meerut, U.P. India. 2014, Annual Report, 2013–14. http://www.iifsr.res.in/sites/default/files/pdf/PDFSR_AR_2013-14.pdf

Jha, D. 2003. An overview of farming systems research in India. *Annals of Agricultural Research* 24(4): 695–706.

Kumar, P, P K Joshi, and P S Birthal. 2009. Demand Projections for food grains in India. *Agricultural Economics Research Review* 22: 237–243. DOI: 10.22004/ag.econ.57405

Mahapatra, I C. 1994. Farming system research – A key to sustainable agriculture. *Fertilizer News* 39(11):13–25.

Mehta, P K. 2009. Micro-level decision for area shift in favour of high-value crops: a case of horticultural crops. *Agricultural Economics Research Review* 22(2): 299. DOI: 10.22004/ag.econ.57414

Mukherjee, S. 2010. Crop diversification and risk: an empirical analysis of Indian states. MPRA Paper No. 35947, http://mpra.ub.uni-muenchen.de/35947/

Narayanamoorthy, A. 2013. Profitability in crops cultivation in India: Some evidence from cost of cultivation survey data. *Indian Journal of Agricultural Economics* 68 (1):104–121. DOI: 10.22004/ag.econ.206325

Pal, R. 2008. Food situation and national economy. *Kisan World*, 35(4): 25–28.

Prasad, V R, M M Reddy, and M V Ramana. 2012. Identification of predominant farming systems and their economics in Telangana region of Andhra Pradesh. *Agricultural Situation in India* 69(5): 239–246.

Saravanakumar, V, and D K Jain. 2008. Technical efficiency of dairy farms in Tamil Nadu, India. *Journal of Indian Society of Agricultural Statistics* 62(1): 26–33.

Saravanakumar, V, K Siddeswaran, A Yasodhagayathri, and S Srinivasan. 2012. Economic analysis and resource use efficiency of predominant farming systems in Tamil Nadu. 3rd International Agronomy Congress, Nov 26–30, 2012, New Delhi, India.

Sharma, B L, and R C Sharma. 2004. Contribution of dairy and crop enterprises to the economy of the rural families in semi-arid region of Rajasthan. *Indian Journal Agricultural Economics* 59(3): 608–609.

Singh, S P, B Gangwar, and M P Singh. 2008. Economics of sugarcane-based farming system in western Uttar Pradesh. *Agricultural Economics Research Review* 21: 109–117. DOI: 10.22004/ag.econ.47367

Sukhatme, P V, B V Sukhatme, S Sukhatme, and C Asok. 1984. Sampling Theory of Surveys with Applications. Iowa State University Press, Ames and Indian Society of Agricultural Statistics, New Delhi.

Velavan, C, and P Balaji. 2012. Crop diversification in Tamil Nadu-A temporal analysis. *Agricultural Situation in India* 52(3): 655–657.

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Economics of demonstrating wheat production technology under rain-fed ecosystems

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Abstract The recommended wheat production technology—including variety, seed rate, and fertilizer dose—was demonstrated under the Farmer FIRST programme of the Indian Council of Agricultural Research, New Delhi during the *rabi* season of 2017 and 2018. The difference in average yield was statistically significant between the demonstration plots (15.70 quintals per hectare ± 1.27) and local check plots (11.93 quintals per hectare ± 1.45). The variation in productivity was less at demonstration plots and the net return was higher (by INR 3,042 per hectare). Adopting the recommended production technologies can enhance wheat production in rainfed areas and make it sustainable.

Keywords Wheat, technology demonstration, rainfed

JEL codes Q12, Q16

Kandi (rainfed) areas have unique agroecological features and cropping systems; the organic matter is restricted, as is the efficiency of water and nutrient use (Ghuman and Sur 2001). Crop and livestock production is completely dependent on rainfall, and returns are difficult to sustain. Wheat is an important crop for the livelihood security of farmers in rainfed ecosystems, and researchers worldwide have attempted to analyse the factors of wheat production, efficiency, and profitability.

Chapagain and Good (2015) analyse 10 years' data to understand yield variability and input efficiency and the yield potential under optimal management for closing yield gaps of wheat. Edreiraa et al. (2018) combine local weather, soil, and agronomic data, and crop modeling in a spatial framework to determine gaps in water productivity and found the gap for wheat to average 10 kg per ha per mm. On the other hand, wheat plants treated with a combination of plant growth promoting rhizobacteria and salicylic acid showed significant increases in leaf protein and sugar content, and these maintained higher chlorophyll content, chlorophyll fluorescence (fv/fm) and performance index under rainfed conditions (Khan and Bano 2019).

Efficiency studies of wheat production under rainfed ecosystems have been carried out. In the rainfed zone of Punjab, Pakistan, the mean technical efficiency of wheat production, 47.1%, signifies the scope of increasing wheat productivity with the same level of technology and input use (Hussain et al. 2012). Al-Feel and Al-Basheer (2012) estimate the mean technical efficiency of wheat production at 63% and suggest that the technical efficiency of wheat production can be improved by using improved varieties and by preparing and irrigating the land at the optimum time.

Mburu et al. (2014) estimated the technical, allocative, and economic efficiencies of wheat farmers in Nakuru

District, Kenya, and find that efficiency is strongly influenced by formal education, extension advice, and farm size. The technical efficiency of wheat production in Ethiopia is determined by sex, age, distance to all-weather roads, livestock holding, group membership, farm size, farm fragmentation, tenure status, and investment in fertilizers (Uma 2017).

All these studies focus on the influence of socio-economic factors on the efficiency of wheat production. Therefore, the demonstration of recommended scientific technologies on farmers' fields is considered to be an effective method for improving the technical efficiency and economic return of crops.

Under the Farmer FIRST (Farm, Innovations, Resources, Science and Technology) programme, an initiative of the Indian Council of Agricultural Research (ICAR), demonstrations of scientific wheat production in *kandi* areas were conducted in Samba district of the Jammu region of Jammu and Kashmir Union Territory by Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST), Jammu. The demonstrations of scientific technologies and improved practices yielded better results than the existing practices (Dhaka et al. 2010; Pal and Saroj 2019).

Technology and credit are considered to be the crucial factors for improving farm incomes in rainfed regions (Rao et al. 2014). This paper attempts to find out the economics of the recommended wheat production technologies demonstrated in the *kandi* areas of Jammu and Kashmir under the Farmer FIRST programme.

Data and methodology

Study area

The Farmer FIRST Programme, conducted in three panchayats of Nud block in Samba district, covered 12 villages: Sarna, Raith, Badla Deonian, Badla Brahmna, Kayani, Patyari, Nangal, Satah, Sarain, Toond, Dheora, and Balore. Each demonstration was conducted on an area of 0.4 hectare. The farmers were provided free critical inputs as per the scientific package of practices recommended by the SKUAST-Jammu. The baseline data for the year 2016–17 and subsequent data for 2017–18 regarding socio-economic characteristics, wheat production, etc. were gathered from sites of demonstration plots and neighbouring local check plots.

Before the recommended scientific interventions were implemented, all the farm families in the selected village clusters were interviewed, and existing farm-level cost-–returns data were collected for the major crops. Out of 755 wheat-growing families, 500 families were selected as the experimental (treatment) group, and the recommended wheat production technology was demonstrated. After the wheat had been harvested, the data were collected again from all 755 families, including the 255 comparison group farmers, to compare the productivity and profits of the check and demonstration plots.

Analytical framework

The double difference method—or difference in differences method—controls for time-invariant characteristics while comparing the beneficiaries and non-beneficiaries of a technology, scheme, or programme (Palanisami et al. 2014). We employ the double difference non-equivalent control group design to identify the difference in productivity between beneficiaries and non-beneficiaries of the Farmer FIRST programme (Table 1).

The specification of the double difference (DD) model is

$$DD = \left[\left\{ \frac{1}{b} \sum_{i}^{b} \left(\bar{Y}_{dt} - \bar{Y}_{dt+1} \right) \right\} \left\{ \frac{1}{nb} \sum_{j}^{nb} \left(\bar{Y}_{lt} - \bar{Y}_{lt+1} \right) \right\} \right]$$

Table 1 Differences in productivity

Particulars	Participants	Non-participants	Difference across groups
Group I Treated (with demonstrations)	D_1	C_1	D_1 - C_1
Group II Control (without demonstrations)	D_0	C_0	D_0 - C_0
Difference across time	D_1-D_0	C_1-C_0	Double difference (D_1 - C_1)-(D_0 - C_0)

where,

DD = the difference between mean changes in wheat yield for beneficiaries and non-beneficiaries;

$\overline{Y}_{dt} - \overline{Y}_{dt+1}$ = difference of mean wheat yield of beneficiaries before & after implementation of project, respectively;

$\overline{Y}_{lt} - \overline{Y}_{lt+1}$ = difference of mean wheat yield of non-beneficiaries before & after implementation of project, respectively;

b = number of beneficiaries; and

nb = number of non-beneficiaries

A positive mean double difference indicates that the demonstrations had a constructive impact on beneficiaries, while a negative mean double difference indicates no impact. The modified form of difference in differences regression involving the personal and socio-economic characteristics of beneficiaries and non-beneficiaries is

$$y_{gt} = \beta_0 + \beta_1 Treat_g + \beta_2 Post_t + \beta_3 (Treat_g \times Post_t) + \beta_i Socioec_i + \varepsilon_{gt}$$

y_{gt} = observed outcome in group s in period t;

$Treat_g$ = dummy variable is '1' if observation is from 'treatment' group in either time period

$Post_t$ = dummy variable is'1' if observation is from post treatment group in either time period

$Treat_g \times Post_t$ = estimation of treatment effect (difference across groups)

$Socioec_i$ = socio-economic variables related to groups

Production efficiency and yield gaps

The production efficiency and yield gaps were assessed using the formulas given by Samui et al. (2000).

$$\text{Production efficiency} = \frac{\text{Yield of a particular crop on the given farm}}{\text{Average yield of that crop in the locality}} \times 100$$

Technology gap = Potential yield – Demonstration yield

Extension gap = Demonstration yield – yield from traditional plots

$$\text{Technology index} = \frac{\text{Potential yield – Demonstration yield}}{\text{Potential yield}} \times 100$$

Other researchers use similar methodologies to assess the gaps in production efficiency and yield (Sharma et al. 2015; Vaid et al. 2017; Arora and Sharma 2019; Kumar et al. 2019).

To assess the validity of the improved efficiency of demonstrated plots compared to the local ones, we apply the independent two-sample t-test under these hypotheses:

H_0: $\mu_1 - \mu_2 = 0$ (the difference between the two population means is 0)

H_1: $\mu_1 - \mu_2 \neq 0$ (the difference between the two population means is not 0)

After the project was implemented, to compare the change in productivity of the local check and demonstration plots, we apply the paired two-sample t-test under these hypotheses:

H_0: $\mu_t - \mu_{t+1} = 0$ (the difference between the two population means is 0)

H_1: $\mu_t - \mu_{t+1} \neq 0$ (the difference between the two population means is not 0)

The impact estimator was considered to be the intention to treat effect, as all the farmer partners were supposed to adopt the recommended interventions and, accordingly, the data of all the beneficiaries was considered for comparison with the control group.

The study involves the impact assessment of technology in a cluster of villages using the data of two consecutive years. No separate data for pre-periods was available for treatment and control groups, and the testing of parallel trends was difficult. Both treatment and control villages were part of the same block for which the yield data were recorded by the revenue authorities, and a parallel trend was assumed.

Results and discussion

Table 2 presents the details of wheat demonstrations conducted and some of the major differences between the practices adopted under frontline demonstrations and traditional farms.

Description of technology

The demonstrations comprised recommended technologies, including improved variety WH-1080 and nutrient application as per package of practices. Traditionally, farmers use farm-saved seeds and the broadcast method of sowing, which resulted in a high

Table 2 Demonstrations

Crop	Particulars	Traditional practices	Frontline demonstrations
Wheat	Area (ha)	107.175	295.45
	Number of farms	255	500
	Variety	PBW-343	WH-1080
	Sowing	Broadcasting	Line sowing
	Nutrient Management(N:P:K)	70:00:00	60:30:20
	Seed rate (kg/ha)	125	100

seed rate per hectare. The farm yard manure available at the local check plots was sufficient and urea the only chemical fertilizer used (Table 2).

In demonstration plots, farmers were provided with an improved variety, WH-1080, recommended for *kandi* areas. The seed was sown in lines and the optimum seed rate of 100 kg per hectare was used. Under demonstrations, sowing was performed with seed-cum-fertilizer drill to ensure proper spacing in line sowing. The application of chemical fertilizers was in the ratio of 60:30:20 N:P:K. Nitrogen was applied in three split doses (half as basal and rest half at 'crown initiation' and 'ear initiation' stage), and phosphorus and potash were applied in full during sowing as basal dose.

Socio-economic and maize production variables

Table 3 presents the descriptive statistics of socio-economic characteristics—age of household head, formal education, farming experience, operational holding, area under wheat, and family size—of wheat growers at the local check plots and at the demonstration plots. The respondents at the local check and demonstration plots are statistically indifferent from each other in respect of age, education, and family size, but statistically different in respect of farming experience, operational holding, and area under wheat crop. The beneficiaries at the demonstration plots had more farming experience, total operational area, and area under wheat than those at the local check plots. At the local check plots, the operational holding was 0.49 ha and the area under wheat 0.29 ha. At the demonstration plots, the operational holding was 0.62 ha and the area under wheat 0.20 ha.

At the local check plots, the mean age of farmers was 51.76 years, the formal education of the household head 5.63 years, the farming experience 28.96 years, and the family size was 4.54 members. At the demonstration plots, the mean age of farmers was 52.36 years, the

Table 3 Socio-economic variables (descriptive statistics)

Particulars	Local check plot	Demonstration plot	t-value	p-value	d.f.
Age of household head (years)	51.76 (±0.66)	52.36 (±0.52)	-0.691	0.490	753.00
Formal education of household head (years)	5.63 (±0.21)	5.53 (±0.18)	0.340	0.734	753.00
Farming experience of household head (years)	28.96*** (±0.69)	31.63 (±0.37)	-3.726	0.000	753.00
Operational holding (ha)	0.49*** (±0.03)	0.62 (±0.03)	-2.86	0.004	752.93
Average area under wheat (ha)	0.29*** (±0.009)	0.20 (±0.002)	12.606	0.000	753.00
Family size (number)	4.54 (±0.06)	4.60 (±0.03)	-0.908	0.364	753.00

***Significant at 1% level

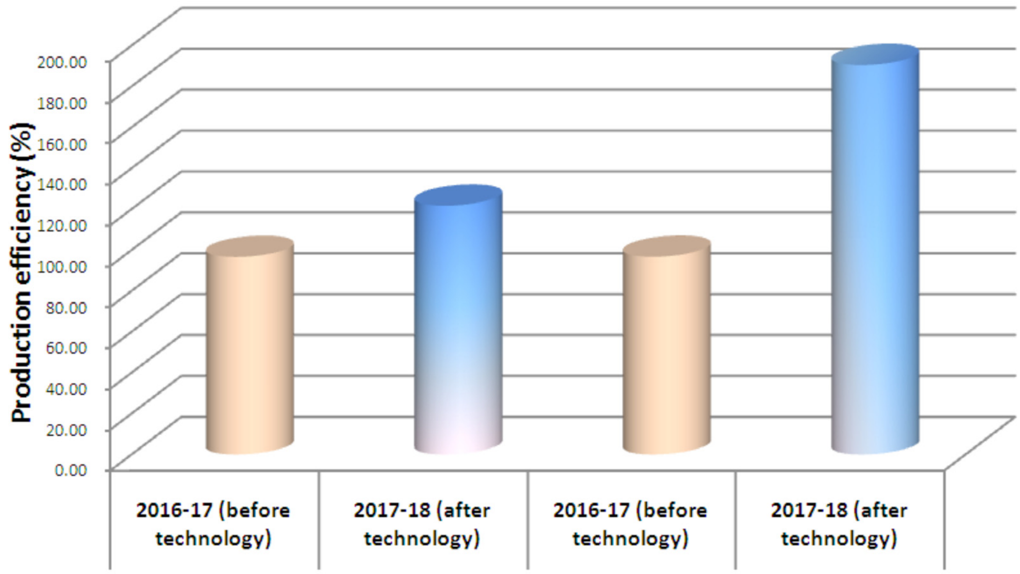

Figure 1 Comparison of production efficiency

formal education of the household head was 5.53 years, the farming experience 31.63 years, and the family size was 4.60 members.

Production efficiency

The production efficiency was assessed at two time periods—before the technology was introduced and afterwards. The efficiency was estimated by considering the average yield in the *kandi* areas of the district recorded in 2015–16 (10.93 quintals per hectare). The production efficiency was 96.61% at the local check plots and 96.68% at the demonstration plots in the base year, 2016–17; these percentages increased, respectively, to 121.68% and 190.48% in 2017–18 (Figure 1).

Physical performance of demonstrations

At the demonstration plots, applying the recommended scientific practices yielded 20.82 q per ha of wheat on average; under traditional practice, the yield was 13.30 q ha. The yield at the demonstration plots was 56.54% higher than in the traditional plots (Table 2). Implementing the project raised production efficiency at the demonstration plots (by 93.50%) and at the local check plots (by 25.95%) (Figure 1). The variance in productivity fell at the demonstration plots from 1.85 in the baseline year to 1.38 but rose at the local check plots from 1.70 in the base year to 2.50. The rise can be attributed to the spillover effect of technology demonstrations at some of the nearby farms (Table 3).

Descriptive statistics of wheat productivity

The overall variations in productivity at the demonstration plots and local check plots across two time periods are depicted as box and whisker plots (Figure 2).

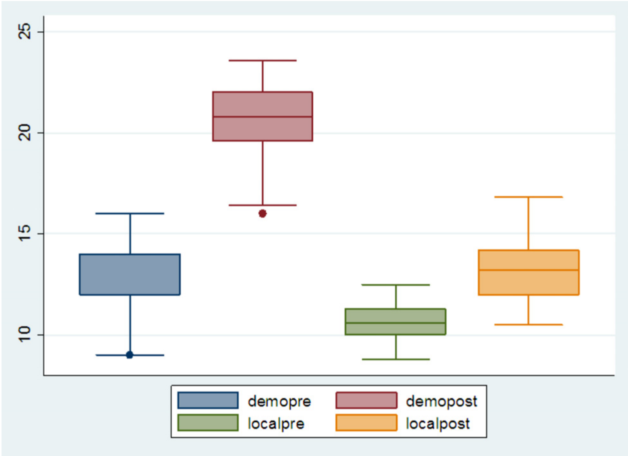

Figure 2 Box and whisker plots of wheat yield

The performance of demonstrations was better in marginal landholdings (56.86%) than at small (55.87%) and medium landholdings (45.28%). A similar trend was witnessed at local check plots (Figure 3).

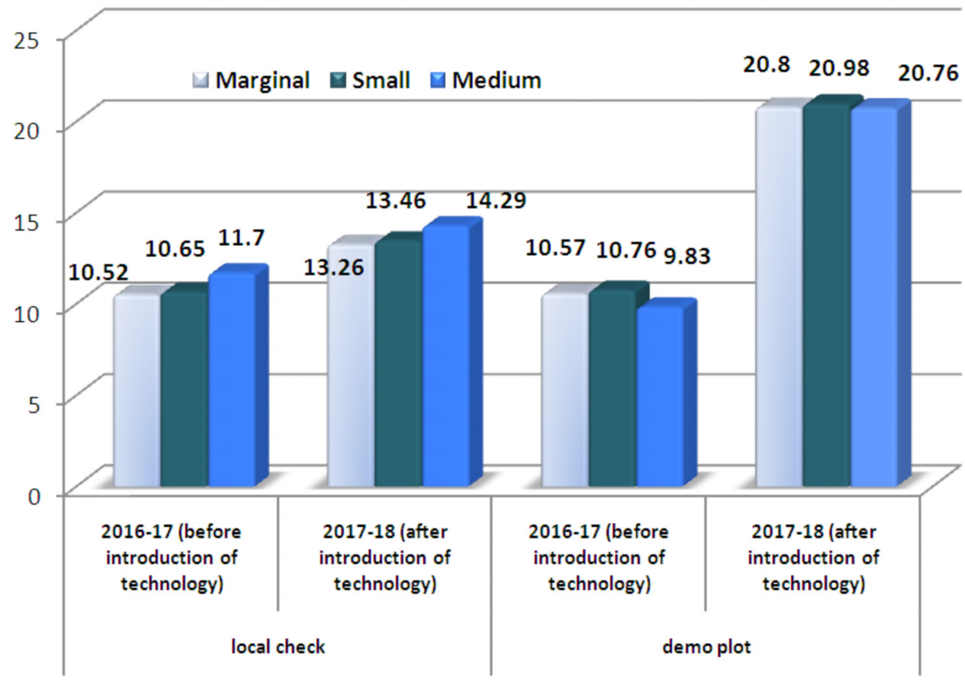

Figure 3 Size of holding and productivity change

Statistical differences in yields and testing of hypothesis

The statistical differences were evaluated by employing the independent two sample t-test and the paired two sample t-test for comparing the yields between the local check plots and the demonstration plots (Table 4) and the base year with the demo year (Table 5), respectively.

The independent two sample t-test revealed that the yield at the local check plots was not statistically different from that of demonstration plots (p=0.860) before the project was implemented; afterwards, however, the yields differed significantly (p=0.000) (Table 4). The paired two-sample t-test revealed statistically different yields (p=0.000) for the base year

Table 4 Wheat productivity, descriptive statistics

Particulars	2016–17 (Baseline)		2017–18		Average of 2 years	
	Local check	Demonstration plots	Local check	Demonstration plots	Local check	Demonstration plots
Mean	10.56	10.58	13.30	20.82	11.93	15.70
Standard error	0.08	0.06	0.10	0.05	0.09	0.06
Median	10.50	10.20	13.50	20.80	12.00	15.50
Mode	10.00	10.00	14.00	20.80	12.00	15.40
Standard deviation	1.31	1.36	1.58	1.18	1.45	1.27
Sample variance	1.70	1.85	2.50	1.38	2.10	1.62
Kurtosis	“0.29	2.88	“0.03	“0.58	“0.16	1.15
Skewness	0.24	1.58	“0.19	0.15	0.03	0.87
Range	5.60	7.00	9.00	7.00	7.30	7.00
Minimum	8.00	9.00	8.00	17.60	8.00	13.30
Maximum	13.60	16.00	17.00	24.60	15.30	20.30
Sum	2692.80	5289.10	3391.50	10410.00	3042.15	7849.55
Count	255	500.00	255	500	255.00	500.00

Table 5 Independent two-sample t-test

	Levene's test for equality of variances		t-test for equality of means		
	F	Sig.	T	df	Sig.(2-tailed)
Comparison of local check (base year) with demo (base year)					
Equal variances assumed	0.590	0.442	–0.176	753	0.860
Comparison of local check (demo year) with demo (demo year)					
Equal variances not assumed	27.685	0.000	–67.105	401.161	.000

and project year at both the local check and demonstration plots (Table 5), indicating that implementing the project raised the yield for both control and treatment groups.

The difference in mean yield between the local check and demonstration plots was statistically non-significant (p=0.860) before the demonstrations were conducted, but statistically significant afterwards. However, the difference in wheat yield before and after demonstrations was statistically significant (p=0.00) at both the local check and demonstration plots.

Technology and extension gaps

The yield of wheat under frontline demonstrations was compared to its potential yield to estimate the technology gap (23.18 q per ha) and the extension gap (7.52 q per ha) (Hiremath et al. 2009).

The large technology gap—attributed mainly to the rain-fed conditions of the district and to the dissimilarity in soil fertility status and landholding size (Table 6)—resulted in the high value of the technology index (52.68%). Lower the value of the technology index, greater the feasibility of the improved practices at the farmer's field.

The extension gap was quite low, due to the demonstration of the complete package of practices for the wheat crop. Educating farmers through various extension means and helping them adopt scientific wheat cultivation practices would narrow the gap further (Table 6).

Medium-size landholdings recorded the highest increase in productivity (111%), followed by marginal (96.78%) and small (94.98%) landholdings (Figure 3).

Economics of frontline demonstrations

Table 7 compares the economics of the recommended wheat production technologies under frontline demonstrations with that of local check plots. The economic analysis considers the variable costs of cultivation: cost of land preparation, seed, fertilizers, labour, agrochemicals, harvesting, and threshing for wheat crop.

The gross returns were calculated by combining the income from grains and straw at the prevailing market price. The gross returns were higher for demonstration plots (INR 33,103 per ha) than at traditional plots (INR 21,014 per ha), as was the B:C ratio (0.727 per hectare at the demonstration plots and 0.534 per hectare at the traditional plots).

Table 6 Paired two-sample t-test

	Paired differences		t-test		
	Mean (SD)	Std. Error Mean	t	df	Sig. (2-tailed)
Comparison of yield under local check during base year with demo year					
Demo year yield – Base year yield	2.74 (±1.36)	0.852	32.138	254	0.00
Comparison of yield under demonstrations during base year with demo year					
Demo year yield – Base year yield	10.24 (±1.81)	0.809	–126.48	499	0.00

Table 7 Technology and extension gaps

	Yield (q/ha)		% increase	Technology gap	Extension gap	Technology index
Potential	Demonstration	Traditional Plots	over local	(q/ha)	(q/ha)	(%)
44.00	20.82	13.30	56.54	23.18	7.52	52.68

Table 8 Economics of wheat at local check and demonstration plots

Particulars	2016–17 (Base year)		2017–18	
	Local check plot	Demonstration plot	Local check	Demonstration plots
Cost of production (INR/ha)	12213.88 (±96.90)	12874.84 (±75.87)	13854.42 (±89.22)	19228.78 (±50.47)
Yield (q/ha)	10.56 (±0.08)	10.58 (±0.06)	13.30 (±0.06)	20.82 (±0.06)
Gross return (INR/ha)	16790.40 (±107.50)	16819.34 (±96.74)	21014.00 (±156.40)	33103.80 (±102.22)
Net return (INR/ha)	4576.52 (±168.26)	3944.50 (±120.09)	7159.58 (±182.69)	13875.02 (±111.70)
B:C ratio	0.399 (±0.01)	0.33 (±0.01)	0.534 (±0.016)	0.727 (±0.006)

The net returns were INR 6,717 higher per hectare at demonstration plots (INR 13,875 per ha) than at the traditional plots (INR 7,159 per ha). Implementing the project raised the net returns at both the demonstration plots (by 81.53%) and the local check plots (by 56.44%), and it reduced the variation in net returns at the demonstration plots. The B:C ratio increased 120% at demonstration plots and 33.83% at local check plots.

The results of the difference in differences estimator revealed that the coefficient of post (time) term was statistically significant at 1% level of significance and had a positive sign. This means that wheat yield was trending up over time. The coefficient of the treatment term had a negative coefficient, which indicates that the wheat yield at the demonstration and local check plots was the same before the project was implemented.

The coefficient of the interaction term (treat × post) had a positive coefficient of 7.502, and it was statistically significant at 1% level of significance. That indicates that the project has increased the yield of wheat in the cluster of villages where the project had been implemented.

The coefficients of age, education, and family size had negative signs, but the coefficients of farming experience, size of holding, and area under wheat had positive signs. However, only the coefficients of age and farming experience were significantly related to wheat yield in selected cluster of villages.

Difference in differences

The double difference regression model was employed to analyse the impact of wheat production technology demonstrated under the Farmer FIRST programme (Table 8). The regression estimates supported the double difference estimates along with the inclusion of growers' socio-economic variables for relaxing the stringent parallelism assumption associated with simple differences.

The coefficient of the treatment variable (β_1= -4.763) estimated the mean difference in wheat yield between the treatment and control groups prior to the implementation of project. Therefore, β_1 represents whatever "baseline" differences existed between the groups before the intervention was applied to the control group.

Similarly, the coefficient of post variable (β_2 = -7.485) provides the expected mean change in outcome from before to after the start of the project among the control

Table 9 Difference-in-differences estimator using ordinary least square (OLS)

Variable	Coefficients	Standard error	t-value
Constant	16.005***	0.458	34.933
Treat	–4.763***	0.231	–20.582
Post	–7.485***	0.215	–34.852
Treat × post	7.502***	0.134	56.033
Age of household head	–0.015***	0.004	–4.399
Formal education of household head	–0.004	0.009	–0.429
Farming experience of household head	0.011***	0.004	2.718
Family size	–0.060	0.041	–1.462
Operational holding	0.030	0.043	0.685
Average area under wheat	0.224	0.363	0.616
F value	2350.19***		
Adjusted R^2	0.933		

***Significant at 1% level

group. Therefore, β_2 reveals the pure effect of time in the absence of the actual intervention. The coefficient of treat × post (β_3= 7.502) represents the difference in differences estimator, which reflects the expected mean change in outcome in the two groups before and after project implementation.

Conclusions

Rain-fed farming is entirely dependent on timely, adequate rain; therefore, production risks and uncertainty cause large variations in productivity in the same agroecological situation, and farmers are reluctant to adopt new interventions. Considering the vagaries of rain-fed farming, demonstrations on the recommended wheat production technology were conducted on farmers' fields under the Farmer FIRST programme. The results of the difference in differences estimator revealed a significant increase in the wheat yield of demonstration plots, and the consistent implementation of the recommended technology minimized the variation in yield under similar agroecological situations. Extension agencies should adopt a cluster approach and focus on the horizontal expansion of rain-fed technologies across different farms. Reducing the variation in yield in a cluster in rain-fed ecosystems helps in building the confidence of farmers in adopting innovative methods and practices.

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References

Al-Feel, M A, and A A R AL-Basheer. 2012. Economic efficiency of wheat production in Gezira scheme, Sudan. *Journal of the Saudi Society of Agricultural Sciences* 11 (1): 1–5. https://doi.org/10.1016/j.jssas.2011.08.001

Chapagain, T, and A Good. 2015. Yield and production gaps in rainfed wheat, barley, and canola in Alberta. *Frontiers in Plant Sciences* 6: 990. 10.3389/fpls.2015.00990.

Dhaka, B, B S Meena, and R L Suwalka. 2010. Popularization of improved maize production technology through frontline demonstrations in south-eastern Rajasthan. *Journal of Agricultural Sciences* 1 (1): 39-42. 10.1080/09766898.2010.11884652

Edreiraa, J I R, N Guilpart, V Sadras, K G Cassman, M K vanIttersum, R L M Schils, and P Grassini. 2018. Water productivity of rainfed maize and wheat: a local to global perspective. *Agricultural and Forest*

Meteorology 259: 364–373. https://doi.org/10.1016/j.agrformet.2018.05.019

Ghuman, B S, and H S Sur. 2001. Tillage and residue management effects on soil properties and yields of rainfed maize and wheat in a subhumid subtropical climate. *Soil & Tillage Research* 58: 1–10. https://doi.org/10.1016/S0167-1987(00)00147-1

Hiremath, S M, and M V Nagaraju. 2009. Evaluation of front line demonstration trials on onion in Haveri district of Karnataka. Karnataka *Journal of Agricultural Sciences* 22 (5): 1092–1093.

Hussain, A, A Saboor, M A Khan, A Q Mohsin, and F Hassan. 2012. Technical efficiency of wheat production in rain-fed areas: a case study of Punjab, Pakistan. *Pakistan Journal of Agricultural Sciences* 49 (3): 411–417.

Khan, N, and A Bano. 2019. Exopolysaccharide producing rhizobacteria and their impact on growth and drought tolerance of wheat grown under rainfed conditions. *PLoS One* 14(9):e0222302.doi: 10.1371/journal.pone.0222302.

Kumar, S., V Mahajan, P K Sharma, and S Parkash. 2019. Impact of front line demonstrations on the production and productivity of moong (Vigna radiata L), mash (Vigna mungo L), rajmash (Phaseolus vulgaris L), lentil (Lens culinaris L) and chickpea (Cicer aeritinum L) under rainfed ecology in mid hills of J&K, India. *Legume Research* 42 (1): 127–133. doi: 10.18805/LR-3816.

Mburu, S, C Ackello-Ogutu, and R Mulwa. 2014. Analysis of economic efficiency and farm Size: a case study of wheat farmers in Nakuru district, Kenya. *Economics Research International* 802706. http://dx.doi.org/10.1155/2014/802706

Pal, B D, and S Saroj. 2019. Do improved agricultural practices boost farm productivity? The evidence from Karnataka, India. *Agricultural Economics Research Review* 32 (Conference): 55–75. https://doi.org/10.5958/0974-0279.2019.00017.X

Palanisami, K., C R Ranganathan, D Suresh Kumar, and R P S Malik. 2014. Enhancing the crop yield through capacity building programs: application of double difference method for evaluation of drip capacity building program in Tamil Nadu State, India. *Agricultural Sciences* 5 (1): 33–42. http://dx.doi.org/10.4236/as.2014.51003

Rao, C A R, J Samuel, S Kumar, B M K Raju, R Dupdal, and B Venkateswarlu. 2014. Role of technology and credit in improving farm incomes in rainfed regions in Andhra Pradesh. *Agricultural Economics Research Review* 27 (2): 187–198. 10.5958/0974-0279.2014.00023.8

Samui, S K, S Maitra, D K Roy, A K Mondal, and D Saha. 2000. Evaluation on frontline demonstration on groundnut. *Journal of Indian Society of Coastal Agriculture Research* 18 (2): 180–183.

Sharma, P K, and S Prakash. 2015. Economic Evaluation of Technology for Promoting Pulses Production in Poonch district of Jammu & Kashmir. *Journal of Community Mobilization and Sustainable Development* 10 (1): 29–33.

Uma, C. 2017. Determinants of technical efficiency of wheat production in Ethiopia: a review. *Journal of Economics and Sustainable Development* 8 (19): 11–15.

Vaid, A, P K Sharma, V Mahajan, B Ajrawat, A Jamwal, S Gupta, and V K Sharma. 2017. Economic impact of frontline demonstrations on basmati rice. *Agro Economist - An International Journal* 4 (2): 79–83. 10.5958/2394-8159.2017.00014.7

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Trends and effects of rainfall on groundwater recharge in Namakkal district of Tamil Nadu: analysis using the Mann–Kendall test and transfer function model

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Abstract Persistent rainfall determines the potential groundwater availability; hence, their association is assessed in this paper. The Mann–Kendall test is used on time series data, and a linear transfer function model is fitted. The Mann–Kendall test shows a negative trend in the groundwater level during the north-east monsoon and an increasing trend in all seasons. The rising trend of rainfall raised groundwater availability throughout the year except during the north-east monsoon. The linear model specifies that rainfall affected the monthly average groundwater level which led to the recharge of the dynamic groundwater level.

Keywords Trend, rainfall, groundwater, Mann–Kendall test, Sen's slope

JEL codes Q25, Q54

Worldwide, groundwater is the most preferred source of water supply, and its rising demand has lowered the water level and made groundwater decline a serious problem. Water in aquifers is not frequently at a persistent level; the water level depends on recharge resulting from the infiltration of precipitation. Rainfall controls the groundwater table. When rainfall is less than normal for a long period, the water flow in rivers and streams slows down, and the water level falls in reservoirs and lakes and, ultimately, wells.

The rate of recharge determines the groundwater table, but the relationship between rainfall and groundwater recharge is not clear, mainly because the changes in groundwater storage have not been observed in a sustained manner and the availability of data is inadequate (Taylor et al. 2013). Groundwater assumes significance in the context of declining contribution of surface water sources, especially when the area irrigated by tanks has been declining steadily since the 1960s (Sivasubramaniyan 2016). The largest component of groundwater use is the water extracted for irrigation (Roopal 2016).

Tamil Nadu is one of the water-starved states in India; more than 60% of its wells show a fall in the groundwater level, and its annual replenishable groundwater resource of the state is estimated at 23.07 billion cubic metres (BCM). The current level of utilization expressed as net groundwater draft of 13.59 BCM is about 60% of the available recharge, while 8.88 BCM (40%) is available for use. The uncontrolled use of the borewell technology has led to the extraction of groundwater at such a high rate that often recharge is not sufficient. The attention to water conservation and re-use, water use efficiency, groundwater recharge, and ecosystem sustainability has been inadequate.

With this view, the Central Ground Water Board, South Eastern Coastal Region is monitoring the water levels in a set of groundwater monitoring dug wells and piezometer wells in Tamil Nadu and Puducherry to study the behaviour of the groundwater table. Analyses of rainfall and water extraction data from satellite records by researchers in India find that diminishing monsoon rainfall has been disturbing groundwater storage (Nature India 2017). Data is required on groundwater resources and levels to assess whether its utilization is sustainable (Valerie et al. 2019). Standardized recharge and rainfall time series demonstrate a clear relationship between rainfall and recharge. Annual recharge is higher (or lower) than the mean value when annual rainfall is also higher (or lower) than the mean rainfall. This trend is confirmed by the observed relationships between the annual groundwater storage balance (the difference in storage between January and December the same year) and the annual rainfall.

Currently, changes in groundwater storage are strongly correlated to rainfall. The increasing pressure on the limited resources requires immediate action for sustainable groundwater resource management. In this context, this study investigates the future scenario of groundwater in Tamil Nadu and proposes policy options to sustain groundwater resources.

Study area and data

Namakkal, a district in Tamil Nadu, is situated in the north-western and western agroclimatic zones, and its climate is hot and dry. The meteorological department follows the standard of four seasons with some local adjustments: winter (January and February); summer (March, April, and May); monsoon (rainy) season (June to September); and a post-monsoon period (October to December). The weather turns hot in March and the temperature reaches the maximum during April and between October and December (District Survey Report, Namakkal District 2019). The river Cauvery is one of the major water sources for the overall socio-economic progress of Namakkal district.

In the context of groundwater levels, the district is categorized as an over-exploited area (Central Groundwater Board, India 2017). Rainfall is the only source of moisture, but the distribution of rainfall is uneven and erratic, and agriculture is mainly rain-fed. The district receives rain under the influence of both the south-west and north-east monsoons. Both the temporal and spatial variability of rainfall influence the cropping pattern, agricultural productivity, and livelihood sustainability. The annual and seasonal rainfall received and its variability affect crop growth and yield and directly influence success or failure. To select suitable crops and take the appropriate mitigating measures, it is essential to study the characteristics of rainfall and the variability of annual and seasonal rainfall.

This study is uniquely based on the secondary data of the monthly groundwater level (mbgl) and rainfall (mm) data of Namakkal district for the period from 2010 to 2018. The data is obtained from the Central Ground Water Board; the State Ground and Surface Water Resources Data Centre, Tamil Nadu; and from the Series of Season and Crop Report (Department of Economics and Statistics, Tamil Nadu 2009–10 to 2017–18).

Trend analysis may be the best approach to assessing the responsiveness of the groundwater level to treatment rainfall in situations where treatment was gradual and widespread. Statistical trend analysis is a hypothesis-testing process (Donald et al. 2011); the null hypothesis (H_O) is that there is no trend and each test has its own parameters for accepting or rejecting H_O.

Mann–Kendall test and Sen's slope estimator

The studies that use trend analysis focus mainly on the null hypothesis of no trend (the type I error). Only a few studies report the competency of the Mann–Kendall test (Mann 1945; Kendall 1975; Gilbert 1987) to successfully recognize the trends. The Mann–Kendall test has been commonly used to statistically detect the monotonic (upward or downward) trends in the hydrometeorological time series, but the trend may or may not be linear (Partal and Kahya 2006; Kumar et al. 2010).

The non-parametric Mann–Kendall test is commonly employed to detect monotonic trends in data series—environmental, climate, or hydrological (Thorsten 2020). The null hypothesis, H_0, is that the data comes from a population with independent realizations and it is identically distributed. The alternative hypothesis, H_a, is that the data follows a monotonic trend. The Mann–Kendall test can be used in place of a parametric linear regression analysis, which can be used to test whether the slope of the estimated linear regression line is different from 0.

Richarde et al. (2015) apply the non-parametric Mann–Kendall and use Sen's methods to determine whether there was a positive or negative trend in rainfall data with statistical significance. A detailed statistical analysis applied to the river flow and rainfall time series of all gauges indicates that rainfall is highly temporally variable and that annual rainfall fell between 1960 and 2000. The Mann–Kendall test statistic is determined by the ranks and sequences of time series rather than the original values, and it is robust when dealing with non-normally distributed data, censored data, and time series with missing values (Hirsch 2011). Fan Wang et al. (2020) describe the Mann–Kendall test as follows.

For a given time series $\{X_i, i = 1, 2, \dots n\}$, the test statistic S

$$\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sgn\ (x_j - x_i) \quad \dots(1)$$

where X_i and X_j are the values of sequence i, j; n is the length of the time series and

$$sgn\ (\theta) = \begin{vmatrix} 1\ if \boldsymbol{\theta} > 0 \\ 0\ if \boldsymbol{\theta} > 0 \\ -1\ if \boldsymbol{\theta} < 0 \end{vmatrix} \quad \dots(2)$$

The statistic *S* is approximately normally distributed when $n \geq 8$, with the mean and the variance of statistics *S* as follows:

$$E(S)=0 \quad \dots(3)$$

$$V(S) = \frac{n(n-1)(2n+5) - \sum_{i-1}^{m} T_1 i\ 9i-1)(2i+5)}{18} \quad \dots(4)$$

On running the Mann–Kendall test on the selected data, if the p-value is less than the significance level α (alpha) = 0.05, H_0 will be rejected. If H_0 is rejected, a trend is indicated in the time series; if H_0 is accepted, no trend is detected. If the null hypothesis is rejected, the result is said to be statistically significant.

Sen's slope estimator

The standard method of estimating the slope of a regression line is based on a least squares estimate, but the method is not valid when the data elements do not fit a straight line, as it is also sensitive to outliers. For estimating the magnitude of a time series trend for the set of pairs (i, x_i) where xi is a time series, the non-parametric procedure, Sen's slope (Sen 1968), is more robust.

$$\text{Sen's slope} = Median \left(\frac{x_j - x_i}{j-i} : i < j\right) \quad \dots(5)$$

where β is Sen's slope estimate. β>0 indicates an upward trend in a time series. Otherwise, the data series presents a downward trend during the time period.

Transfer function model

Rainfall influences aquifer recharge. To find out whether rainfall accelerates aquifer recharge in the study area, we mathematically estimate the relationship between monthly rainfall and monthly average groundwater level. Stochastic time series multivariate models can be constructed by the transfer function modelling technique involving two or more input variables and their dynamic relationships with the output. The main feature of this model is that the time evolution of rainfall and groundwater level would be linked to their previous and current values for both variables.

Yi and Lee (2004) find that x_t and y_t can follow linear processes and a linear relationship can be proposed between both time series. The residual e_t will also be a time series, likely to follow an autoregressive moving average with exogenous variables (ARMAX) model as an extension of linear regression to the time series area.

We constructed transfer function models for the data on the rainfall and groundwater levels based on time series methods using the steps necessary to model the stochastic time series process (Knotters and Bierkens 2000).

$$y_t = y_t * + N_t \quad \dots(6)$$

$$y_t * = \sum_{i=1}^{p} a_i\, y *_{t-1} + \sum_{j=o}^{q} b_j\, x_{t-j-k} \quad \dots(7)$$

$$N_t - \mu = \sum_{i=1}^{r} c_i\, (N_{t-i} - \mu) + \sum_{j=1}^{s} d_j\, \varepsilon_{t-j} + \varepsilon_t \quad \dots(8)$$

Where, y_t is the groundwater level at time t; y_t* is the groundwater level attributed to the rainfall value; N_t is the unexplained part, or noise term; x_t is the average rainfall attributed to the time step t–1 to t; k is the delay factor of relation between input and output; μ is the expected value of the noise term; a_i is the autoregressive parameter of the transfer function model of order i = 1, … p; b_j is the moving average parameter of the transfer model of order j = 1, …; c_i is the autoregressive parameter of the noise model of order i = 1, … r; d_j is the moving average parameter of the noise model of order j = 1, … s; and e_t is the white noise with mean zero and constant variance ε^2.

The transfer function model orders such as p, q, r, and s were kept for comparing different models with different parameterization methods. By applying the selected model orders in Equations 4–6, the resulting model is

$$y_t = y_t^* + N_t \quad \ldots(7)$$

$$y_t^* = a_1 (y^*_{t-1}) + x_t \quad \ldots(9)$$

$$N_t - \mu = c_1 (N_{t-1} - \mu) + \varepsilon_t \quad \ldots(10)$$

If the model order of the autoregressive parameter of the noise model is taken to be same as the autoregressive parameter of the transfer model—i.e., $c_1 = a_1$—the transfer function model of Equations 7–8 can be reduced to a special case of the transfer function model, also known as the ARX model:

$$y_t - \mu = a_1 (y_{t-1} - \mu) + b_0 (x_t) - \varepsilon_t \quad \ldots(11)$$

As a good prediction model, the residuals are used to examine the goodness of fit of the model that meets the requirements of a white noise process. If the model is not suitable, a new model should be identified. The steps of parameter estimation and diagnostic checking are repeated many times until an optimal model is selected. The last selected model is used to forecast the value.

Effect of rainfall on groundwater recharge

The periodic data on rainfall and groundwater level are important to study the fluctuation trends and access the groundwater potential. Table 1 precises the statistical range of both ground water level and rainfall for all the season.

Table 2 Mann–Kendall trend test and Sen's slope—south-west monsoon

Particulars	Rainfall	Groundwater level
Kendall's tau	0.167	0.444
S value	6.000	16.000
Var(S)	92.000	92.000
p-value	0.602	0.118
Sen's slope	7.800	0.514

The seasonal values of rainfall and groundwater levels were plotted for each of the four seasons to obtain the seasonal trend in the variables by applying the Mann–Kendall test. Sen's slope is considered in measuring the magnitude of change in the study variables.

The season-wise resultant graphs are presented with the line of best fit and the equation of the line as in the graphs. The positive Sen's slope (Table 2) represents the increasing trend (Figure 1) of rainfall in the south-west monsoon and winter (Figure 3). The decreasing trend (negative Sen's slope (Table 3 and Table 4) is observed in the north-east monsoon season (Figure 2). The rainfall trend is considerably stable during summer (Figure 4). Sen's slope and the Kendall tau statistic show a negative trend in the north-east monsoon. The groundwater level shows an increasing trend in all the four seasons. The rising trend of rainfall—robust by a relatively steep slope of the best-fit line—raises groundwater availability significantly (Figure 1 and Figure 3).

The congruent increasing trends of winter rainfall and groundwater level lead to the rising trend of

Table 1 Descriptive statistics of groundwater level (mbgl) and rainfall (mm)

Statistic	South West Monsoon		North East Monsoon		Winter		Summer	
	GWL (mbgl)	Rainfall (mm)	GWL (mbgl)	Rainfall (mm)	GWL (mbgl)	Rainfall (mm)	GWL (mbgl)	Rainfall (mm)
Minimum	3.50	0.00	4.35	57.50	4.35	0.00	6.06	63.70
Maximum	16.82	258.80	12.47	429.00	13.75	26.80	15.83	237.50
Median	11.56	35.40	11.08	251.60	9.69	6.90	11.94	138.15
Mean	10.76	56.98	10.36	257.54	9.50	8.66	11.13	137.98
Variance (n-1)	8.56	3185.04	5.87	10812.06	9.35	101.92	9.60	3063.66
Std deviation(n-1)	2.93	56.44	2.42	103.98	3.06	10.10	3.10	55.35

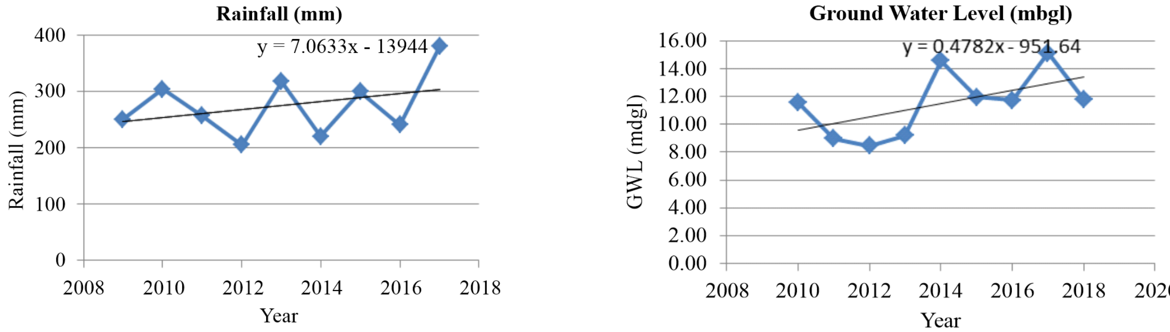

Figure 1. South West Monsoon (June - September)

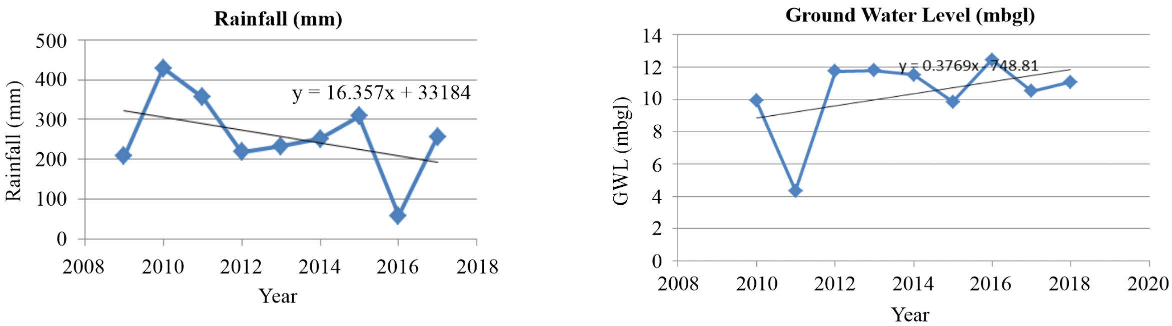

Figure 2. North East Monsoon (October - December)

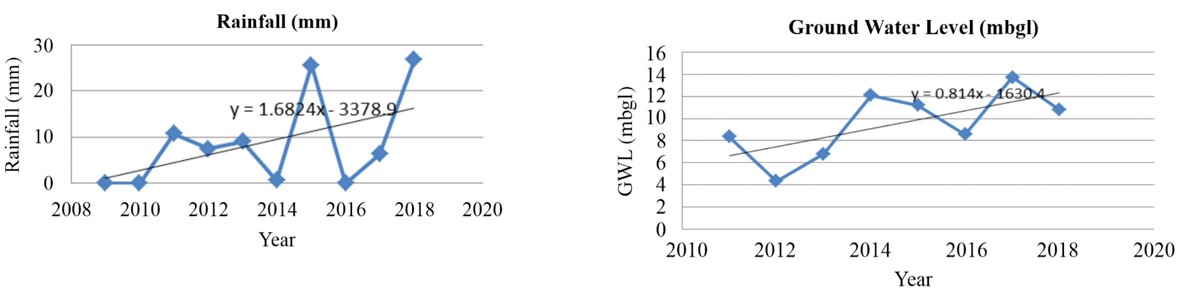

Figure 3. Winter (January - February)

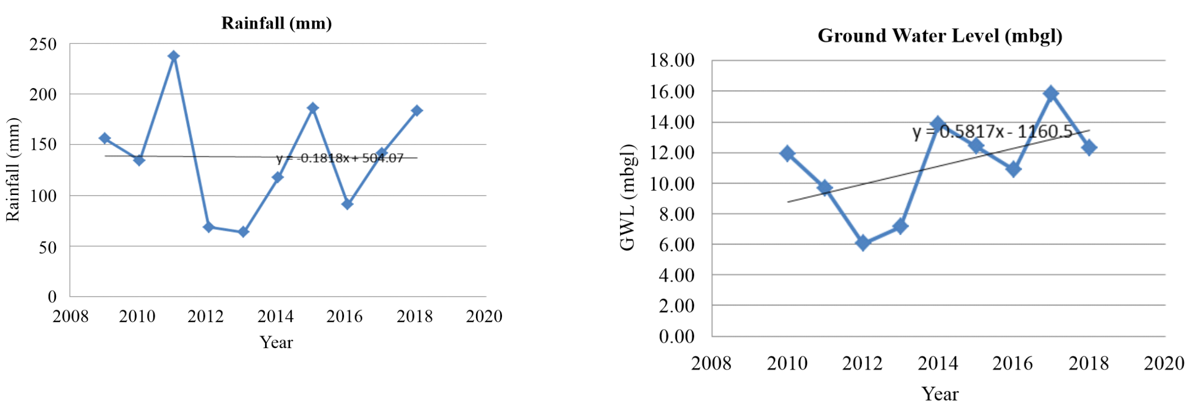

Figure 4. Summer (March - May)

Table 3 Mann–Kendall trend test and Sen's slope—north-east monsoon rainfall

Particulars	Rainfall	Groundwater level
Kendall's tau	–0.056	0.167
S value	–2.000	6.000
Var(S)	92.000	92.000
p-value	0.917	0.602
Sen's slope	–14.346	0.162

Table 4 Mann–Kendall trend test and Sen's slope—winter rainfall

Particulars	Rainfall	Groundwater level
Kendall's tau	0.322	0.429
S value	14.000	12.000
Var(S)	121.333	65.333
p-value	0.238	0.174
Sen's slope	1.600	0.847

groundwater availability in the summer (Table 5). The trends of the variables in all seasons are statistically insignificant, but Sen's slope was positive for groundwater level for all the seasons. Overall, the patterns show that rainfall stimulates an increase in the level of seasonal groundwater and that the groundwater level reflects the effect of rainfall.

Linear transfer function model

We conduct the unit root test to check the variables—monthly rainfall and groundwater level—for stationarity. The Dickey–Fuller test and the KPSS test statistics (p-value at significance level at alpha=0.05) prove that both monthly rainfall and groundwater level have stationarity. To identify the time series model structure, we conducted autocorrelation and partial

Table 5 Mann–Kendall trend test and Sen's slope—summer

Particulars	Rainfall	Groundwater level
Kendall's tau	0.022	0.333
S value	1.000	12.000
Var(S)	125.000	92.000
p-value	1.000	0.251
Sen's slope	1.014	0.608

autocorrelation analyses on the level of rainfall and groundwater. As estimated, the autocorrelation function plot shows that the monthly rainfall and water level data have significant autocorrelation due to seasonality.

The time delay of the influence of the monthly rainfall on the monthly average groundwater level is considered, and the linear transfer function model is employed for the number of times with different numbers of the parameters of the respective models. The cross-correlation between rainfall and groundwater level data is significant, and the time delay parameter k was fixed as zero ($k = 0$) in the linear transfer function model for order fixation.

The time delay of the influence of the monthly rainfall on the monthly average groundwater level is considered, and the linear transfer function model is employed for the number of times with different numbers of the parameters of the respective models. The order for autoregression and moving average for transfer function model is assigned as numerator and denominator and the model is estimated. The results of the various models of the monthly average groundwater levels using monthly rainfall are given in Table 6.

The construction of each model is indicated by orders of autoregressive (r) and moving average (s) and time delay (k) of the model denoted as r- s -k.

The developed transfer function models were evaluated by means of specified statistics: R-squared (high R^2), root mean square error (low RMSE), mean absolute percent error (low MAPE), and Bayesian information criteria (low BIC). These criteria are desirable for the adequacy of a model.

Table 6 shows only nine comparatively well-performed models; the table depicts that the model with $r=1$, $s=2$ and $k=0$ process has the maximum number of lowest values of all the selected criteria RMSE, MAPE, BIC with the highest coefficient of determination R^2. Hence, the ARMAX (1,2,0) model is selected and validated with respective R^2 for forecasting the data series.

The results from the linear model reliably specify that the impact of rainfall in the last two months starting from a given month affected the monthly average groundwater level, which led to the recharge of the dynamic groundwater in the district in that period. This result is in line with the finding in Mohanasundaram

Table 6 Selection of ARIMA models

Model selection criterion/r-s-k	1 1 0	1 2 0	1 3 0	2 1 0	2 2 0	2 3 0	3 1 0	3 2 0	3 3 0
R-squared	0.810	0.819	0.814	0.810	0.818	0.802	0.814	0.818	0.804
RMSE	1.331	1.348	1.357	1.349	1.338	1.344	1.359	1.357	1.313
MAPE	8.271	8.239	8.385	8.245	8.441	8.263	8.574	8.415	8.244
Normalized BIC	1.026	0.902	1.138	1.027	1.105	1.214	1.140	1.233	1.264

et al. (2017), which use transfer function models to develop a statistical relationship between monthly rainfall and groundwater levels in the Adyar River basin in Chennai.

Pre-whitened rainfall and water levels were correlated, and a lag of one month was observed between rainfall and groundwater levels. The impacts of declining monthly rainfall in the north-west monsoon (October to December) are possibly being reflected in the increasing trend of monthly average groundwater levels in the winter (December to February). By the same token, the observations from model simulation studies also substantiate the observations from the Mann–Kendall test statistic and Sen's slope estimator—an increase in the rainfall induces the availability of groundwater in all seasons.

Conclusions

The periodical fluctuations in rainfall and groundwater level in Namakkal district of Tamil Nadu were statistically discovered and the relationship between these two variables established by their time series data. The Mann–Kendall test performed on the time series data of seasonal rainfall and groundwater levels in the district showed an increasing trend during the 2009–2018 period. The positive Sen's slope also represented the increasing trend of rainfall in the south-west monsoon and winter; in the north-east monsoon, a decreasing trend (negative Sen's slope) was observed. The Sen's slope and Kendall tau statistic show a negative trend in the north-east monsoon.

In the case of the groundwater level, an increasing trend is seen in all the four seasons. The rising trend of rainfall is robust, by a relatively steep slope of the best-fit line, and it raised groundwater availability significantly. The patterns show that rainfall stimulates an increase in the level of seasonal groundwater and that the groundwater level reflects the effect of rainfall. Although the time delay of the influence of monthly rainfall on monthly average groundwater level is considered, the linear transfer function model is employed for the number of times with different parameters of the models.

The developed transfer function models were evaluated by the means of specified statistics: R-squared (High R^2), root mean square error (low RMSE), mean absolute percent error (low MAPE), and Bayesian information criteria (low BIC). These criteria are desirable for the adequacy of a model. Among the nine well-performed models, the model with the r=1, s =2 and k=0 process has the maximum number of lowest values of all the selected criteria RMSE, MAPE, BIC with highest coefficient of determination R^2. This model is selected and validated with respective R^2 for forecasting the data series.

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References

Central Ground Water Board (CGWB), India. 2017. Dynamic groundwater resources assessment of India. http://cgwb.gov.in/GW-Assessment/GWRA-2017-National-Compilation.pdf

Department of Economics and Statistics. Season and crop report. 2009-10 to 2017-18, Tamil Nadu.

District Survey Report for Sand Mining, Namakkal district. 2019. https://cdn.s3waas.gov.in/s3b9228e0962a78b84f3d5d92f4faa000b/uploads/2019/06/2019062065.pdf

Donald W Meals, Jean Spooner, Steven A Dressing, and Jon B Harcum. 2011. Statistical analysis for monotonic trends, Tech Notes 6. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA, p.23 https://www.epa.gov/sites/production/files/2016-05/documents/tech_notes_6_dec2013_trend.pdf

Fan Wang, Wei Shao, Haijun Yu, Guangyuan Kan, Xiaoyan He, Dawei Zhang, Minglei Ren, and Gang Wang. 2020. Re-evaluation of the power of the Mann-Kendall test for detecting monotonic trends in hydrometeorological time series. State key laboratory of hydroscience and engineering. *Frontiers in Earth Science.* https://doi.org/10.3389/feart.2020.00014

Gilbert, R O. 1987. *Statistical methods for environmental pollution monitoring*, Wiley, NY. https://www.osti.gov/servlets/purl/7037501

Hirsch, R M. 2011. A perspective on nonstationarity and water management. *Journal of the American Water Resources Association* 47: 436–446. doi: 10.1111/j.1752-1688.2011.00539.x

Kendall, M G. 1975. Rank correlation methods, 4th edition, Charles Griffin, London.

Knotters, M, and M F P Bierkens. 2000. Physical basis of time series models for water table depths. *Water Resources Research* 36 (1): 181–188. doi:10.1029/1999WR900288.

Kumar, V, S K Jain, and Y Singh. 2010. Analysis of long-term rainfall trends in India. *Hydrological Sciences Journal*, 55(4): 484-496. https://doi.org/10.1080/02626667.2010.481373

Mann, H B. 1945. Non-parametric tests against trend, *Econometrica.* 13(3): 245-259. https://www.jstor.org/stable/1907187.

Mohanasundaram, S, Balaji Narasimhan, and G Suresh Kumar. 2017. Transfer function noise modelling of groundwater level fluctuation using threshold rainfall-based binary-weighted parameter estimation approach. *Hydrological Sciences Journal.* 62(1): 36–49. https://www.tandfonline.com/doi/full/10.1080/02626667.2016.1171325.

Nature India. 2017. Monsoon rainfall changes affecting groundwater level. 7 February. doi:10.1038/nindia.2017.18

Partal, T, and Kahya, E. 2006. Trend analysis in Turkish precipitation data. *Hydrological Processes*, 20(9): 2011-2026. https://doi.org/10.1002/hyp.5993

Richarde Marques da Silva, Celso A G Santos, Madalena Moreira, Joao Corte-Real, and Valeriano C L Silva. 2015. Rainfall and river flow trends using Mann–Kendall and Sen's slope estimator statistical tests in the Cobres River basin. *Natural Hazards.* 77(3): 1205–1221. https://link.springer.com/article/10.1007/s11069-015-1644-7.

Roopal Suhag. 2016. Overview of Ground Water in India. http://old.prsindia.org/administrator/uploads/general/1455682937~~Overview%20of%20Ground%20Water%20in%20India.pdf

Sen, P K. 1968. Estimates of the regression coefficient based on Kendall's Test. *Journal of the American Statistical Association* 63: 1379-1389.

http://dx.doi.org/10.1080/01621459.1968.10480934

Sivasubramaniyan, K. 2016. Performance of irrigation in Tamil Nadu: a macro perspective. MIDS Working Paper No. 224, p.23. https://www.mids.ac.in/assets/doc/WP_224.pdf

State Ground and Surface Water Resources Data Centre, Water Resources Department, Public Works Department, Government of Tamil Nadu. nd. Average groundwater level status compared with previous year—Tamil Nadu. http://www.groundwatertnpwd.org.in/avwl_status.htm

Taylor R G, Todd M C Kongola, L Maurice, E Nahozya, H Sanga, and A M Mac Donald. 2013. Evidence of the dependence of groundwater resources on extreme rainfall in East Africa. *Nature Climate Change* 3:374–378. https://doi.org/10.1038/nclimate1731

Thorsten P. 2020. Non-parametric trend tests and change-point detection. p 2. https://cran.r-project.org/web/packages/trend/vignettes/trend.pdf

Valerie Kotchoni, D O Jean-Michel Vouillamoz, M Fabrice, A Lawson, Philippe Adjomayi, and Richard G Taylor. 2019. Relationships between rainfall and groundwater recharge in seasonally humid Benin: A comparative analysis of long-term hydrographs in sedimentary and crystalline aquifers. *Hydrogeology Journal* 27: 447–457. https://link.springer.com/article/10.1007/s10040-018-1806-2?shared-article-renderer.

Yi, M J, and Lee K K. 2004. Transfer function-noise modelling of irregularly observed groundwater heads using precipitation data. *Journal of Hydrology*. 288 (3). 272–287. doi:10.1016/j.jhydrol.2003.10.020.

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Economic impact assessment of conservation agriculture on small and marginal farm households in eastern India

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Abstract This study compares the economic impacts of conservation agriculture and conventional farming systems in the Lower Gangetic alluvial tract of West Bengal, India. Under conservation agriculture the overall gain in system productivity is 2.40%. The estimated change is attributable to the relative change in input use. Technology had a minor effect on the change in crop productivity, and the reduced use of machine labour, bullock labour, and plant protection chemicals had a significant positive impact. Farms that practised conservation agriculture averaged a 12.88% higher return per rupee of investment than conventional farm families.

Keywords Economic impact, conservation agriculture, technology, decomposition

JEL codes Q10, Q51

Attaining food security for a growing population and alleviating poverty while sustaining agricultural systems is an urgent imperative worldwide. In the recent past, most Asian countries have been challenged by the depletion of natural resources, negative impacts of climatic variability, spiraling cost of inputs, and volatile food prices.

The principal indicators of the non-sustainability of agricultural systems are soil erosion, depletion of soil organic matter, and the soil salinization processes. The specific reasons are the decline in soil organic matter induced by intensive tillage, soil structural degradation, water and wind erosion, reduced water infiltration rates, surface sealing and crusting, soil compaction, insufficient return of organic material, and monocropping.

Traditional agriculture is based on intensive tillage, and it is highly mechanized. Traditional agriculture is held responsible for soil erosion problems, surface and underground water pollution, and increased consumption of water (Wolff and Stein 1998). Conventional tillage methods may not be economically or environmentally sustainable in the long run. A paradigm shift is essential for future productivity gains in farming practices. The unsustainable parts of conventional agriculture (ploughing/tilling the soil, monoculture) must be eliminated while sustaining the natural resources (Bhan et al. 2014).

The concept of conservation agriculture evolved as a response to the global concerns of the sustainability of agriculture. Conservation agriculture is a resource-saving agricultural production system that aims to intensify production and raise yields, while enhancing the natural resource base, by complying with three interrelated principles and good plant nutrition and pest management practices (Abrol and Sangar 2006). Many researchers argue that conservation agriculture can improve crop productivity, food security, the net income of farmers, and environmental protection (Patzek 2008; Govaerts 2009; Verhulst et al. 2010); the practice has steadily grown worldwide to cover about 8% of the world's arable land (124.8 million hectares) (FAO 2012).

In the late 1960s the green revolution introduced in South Asia modern, short-duration, dwarf varieties of wheat and rice, and modern chemical fertilizers and irrigation. Dependent on strong policy support, including prices, the green revolution was an ongoing effort, and its practices continued to evolve even decades since its introduction (Hobbs et al. 2017). Rice–wheat emerged as the major cropping system in the Indo-Gangetic Plains of South Asia (Timsina and Connor 2001; Gupta et al. 2003; Gupta and Seth 2007). In the rice–wheat cropping system, rice is grown in the warm and wet summer season and wheat in the cooler winter months, and minor crops (maize, legumes, pulses, vegetables and others) are grown in winter or on higher land in summer.

The production of cereals increased significantly, and provided the calories needed for a growing population, but many studies report that intensive irrigated degraded the natural resource base, and rice yields either declined or stagnated after the 1980s (Flinn and De Datta 1984; Cassman and Pingali 1995; Nambiar 1988; Pingali et al. 1997; Greenlands 1997; Yadav et al. 2000; Dawe et al. 2000; Kumar and Yadav 2001). However, most of these studies were based on experimental data, designed with a specific objective, and conducted under controlled environments (fixed nutrient doses, variety, other management practices, etc.) in the research farms and adaptive research trials. These studies provide the impression that the productivity impact of technological progress has been vanishing in the irrigated systems. Chatterjee et al. (2015) estimate the total factor productivity growth of rice in the eastern states of India over four decades (1971–72 to 2010–11) at 3.03%, and conclude that the effect of the green revolution was most prominent between the 1980s and the 1990s, but it declined after the 1990s, because factor and resource overuse reduced soil fertility and total factor productivity stagnated.

At this juncture, the concept of organic agriculture was introduced for the long-run sustainability of rice–wheat cropping systems. After 2010, the concept of conservation agriculture was introduced in the Indo-Gangetic plains of India (Hobbs et al. 2017). To date, agricultural production systems based on conservation agriculture have been adopted mainly on large commercial farms. Sustained practice by smallholder farmers is an exception, though examples may be found in Brazil, Ghana, Zambia, Zimbabwe, and the Indo-Gangetic Plains of India (Ekboiret al. 2002; Haggblade and Tembo 2003; Bolligeret al. 2006; Wall 2007; Erenstein and Laxmi 2008; Erenstein 2009; Erenstein et al. 2012; Thierfelder and Wall 2012; Wall et al. 2013).

The potential impact has been examined by numerous research projects applying methods like cost-benefit analysis, case studies, econometrics, meta-analysis, and linear programming. This study conducts an economic impact assessment of conservation agriculture innovations on the farm income, system productivity, and various input use practices of small and marginal farm households in the Lower Gangetic Plains of West Bengal, India. The study compares their impact with that of traditional farming practices and evaluates the technological gap—by fitting an econometric model consisting of multiple regression analysis using the ordinary least squares (OLS) method of estimation. The study also compares the regression coefficients using the decomposition method formulated by Bisaliah (1977).

Materials and methods

Conceptual framework

This study sets out to test two major hypotheses.

The null hypothesis, H_0, is that there is no significant change in the system productivity of conservation agriculture as compared to conventional farming in the Lower Gangetic Plains of West Bengal.

The corresponding alternative hypothesis, H_1, is that there is significant change in system productivity of conservation agriculture as compared to conventional farming in the Lower Gangetic Plains of West Bengal.

Sampling strategy, stratification, and description of data

The study was conducted in 2019–20. It focuses on three blocks—Haringhata, Chakdaha, and Krishnanagar-I— of Nadia district, West Bengal. The district lies in the alluvial Lower Gangetic Plains. The crop + livestock farming system is followed, and the cropping pattern is diversified. Paddy is the major staple food crop cultivated in rain-fed as well as in irrigated conditions; the other crops grown are mustard, jute, pulses, and vegetables. About 85–90% of the farms in the region are marginal farms, and the landholding size averages 0.83 ha. Farmers have little ability to bear risk and interest in experimentation. Farm households practise conservation agriculture under reduced tillage condition and incorporate their crop residue in the field. Mulching with straw and polythene to keep the soil moisture intact is another usual practice in this region.

We evaluate the socio-economic parameters of the 40 sample farm households—20 each from conservation and conventional farming situations (Table 1). We compile the data on the production and productivity of the crops cultivated, along with their prices and returns, and the input costs and quantities. In the cropping season the sample farm households grow winter rice, summer rice, mustard, jute, lentil, and dolichos bean (Table 2). We compute the system rice equivalent productivity and system input use for each household.

Empirical strategy

To sort out the contribution of technology and resource use differences from the total productivity difference between the two farming practices, we specified the methods of the log linear production function (Cobb-Douglas production function) for both technologies:

$$Y = aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}X_6^{b6}\, X_7b^7\, X_8^{b8}ui \qquad \ldots(1)$$

Table 1 Summary statistics of socio-economic status for sample farm households

Parameters	Units	Conservation agriculture households		Conventional agriculture households		Total farm households under conservation and conventional farming situations	
		Mean	SD	Mean	SD	Mean	SD
Farmer's age	Years	50	10.91	52	8.76	51	9.83
Sex/Gender	Code	1	0.22	1	0.00	1	0.16
Education	Code	3	0.80	3	0.68	3	0.74
Religion	Code	1	0.50	1	0.00	1	0.41
Caste	Code	2	1.02	2	1.04	2	1.04
Cultivated own land	Hectare	1.16	0.87	0.72	0.27	0.94	0.68
Leased-in land	Hectare	0.02	0.06	0.16	0.31	0.09	0.23
Leased-out land	Hectare	0.02	0.07	0.03	0.08	0.02	0.07
Total operational holding	Hectare	1.16	0.89	0.86	0.43	1.01	0.71
Non-farm income	INR/annum	46,600	79,018	42,000	79,647	44,300	78,344
Total valuation of current assets (including land, pond, dwelling house, and farm machinery)	INR/annum	66,58,085	45,67,857	48,35,690	16,44,945	57,46,888	35,12,115
Gross return from crops	INR/annum	3,69,577	1,87,190	2,43,320	1,57,513	3,12,551	1,83,364
Gross return from animals	INR/annum	26,926	25,038	22,480	20,660	24,703	22,157
Total consumption expenditure	INR/annum	2,42,531	1,99,685	2,30,403	2,16,186	2,36,467	2,05,505

SD, Standard deviation
Note: Code for Sex/Gender: Male-1 Female-2 Education: Illiterate-1 Up to primary-2 High school-3 Graduate and above-4 Religion: Hindu-1 Muslim-2 Caste: Scheduled Caste-1 Scheduled Tribe-2 Other Backward Classes-3 General-4 Others-5

Table 2 Various crops identified among sample farm households

Items	
Crops identified under conservation and conventional farming	Winter rice, summer rice, mustard, jute, lentil, Dolichos bean

where,

Y is the system rice equivalent yield (kg ha^{-1});

X_1 is the total quantity of seed used (kg ha^{-1});

X_2 is the total quantity of NPK used (kg ha^{-1});

X_3 is the total quantity of organic manure used (kg ha^{-1});

X_4 is the total hour of irrigation given (hour ha^{-1});

X_5 is the total quantity of plant protection chemicals used (g/ml ha^{-1});

X_6 is the total hour of machine labour used (hour ha^{-1});

X_7 is the total hour of bullock labour used (pair hour ha^{-1});

X_8 is the total person-days of human labour used (person-days ha^{-1});

u_i is a random disturbance or error term in conformity with the OLS assumptions;

b_i is a regression coefficient of the respective parameters; and

a is a scale parameter or intercept.

We aim to calculate the difference in productivity between the two farming situations. Therefore, we specify the production function on a per-hectare basis and convert the productivity of various crops cultivated by farm households under the two situations into the respective rice equivalent yield (REY).

$$SREY = Rice\ \ yield + [Crop(1)\,yield \times \frac{price\,of\ crop(1)}{price\,of\ Rice}] + [Crop(2)\,yield \times \frac{price\,of\ crop(2)}{price\,of\ Rice}] + \dots\dots\dots + [Crop(n)\,yield \times \frac{price\,of\ crop(n)}{price\,of\ Rice}]$$

Before proceeding with the decomposition analysis of the system productivity differences, it is necessary to determine whether there is a structural break in the production relations between the two farming types. We estimate the output elasticities by the OLS method by fitting the log linear regression separately. We run the pooled regression analysis in combination with those for the two different situations, including a dummy variable for farmers who follow conservation agriculture. The dummy variable was set at 1 for conservation agriculture and 0 for conventional farming. These two types differ in their number of tillage operations: conservation farming includes reduced to zero tillage whereas conventional farming includes more tillage operations. The following equations were estimated by identifying the structural break.

$$LnY_{cons} = Ln\beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \beta_4 LnX_4 + \beta_5 LnX_5 + \beta_6 LnX_6 + \beta_7 LnX_7 + \beta_8 LnX_8 + u_{cons} \quad \dots(2)$$

$$LnY_{conv} = Ln\alpha_0 + \alpha_1 LnX_1 + \alpha_2 LnX_2 + \alpha_3 LnX_3 + \alpha_4 LnX_4 + \alpha_5 LnX_5 + \alpha_6 LnX_6 + \alpha_7 LnX_7 + \alpha_8 LnX_8 + u_{conv} \quad \dots(3)$$

$$LnY_{pooled} = Ln\,\gamma_0 + \gamma_1 LnX_1 + \gamma_2 LnX_2 + \gamma_3 LnX_3 + \tilde{a}_4 LnX_4 + \gamma_5 LnX_5 + \gamma_6 LnX_6 + \gamma_7 LnX_7 + \gamma_8 LnX_8 + \gamma_9 LnX_9 + u_{pooled} \quad \dots(4)$$

Equation 2 represents the multiple regression equations for conservation cultivators, Equation 3 for conventional cultivators, and Equation 4 represents the pooled regression model, including conventional and conservation cultivators and a dummy variable (X_9).

Decomposition and analytical model

We estimate Equations 2 and 3 using the OLS technique. The production function is per unit area (hectare), and multicollinearity was not a problem—as indicated by the zero-order correlation matrix. Taking the difference between Equations 2 and 3, performing slight algebraic manipulations, and rearranging some terms, we arrived at this decomposition model:

$$[LnY_{cons} - LnY_{conv}] = [Ln\beta_0 - Ln\alpha_0] + [LnX_{1conv}(\beta_1\text{-}\alpha_1) + LnX_{2conv}(\beta_2\text{-}\alpha_2) + LnX_{3conv}(\beta_3\text{-}\alpha_3) + LnX_{4conv}(\beta_4\text{-}\alpha_4) + LnX_{5conv}(\beta_5\text{-}\alpha_5) + LnX_{6conv}(\beta_6\text{-}\alpha_6) + LnX_{7conv}(\beta_7\text{-}\alpha_7) + LnX_{8conv}(\beta_8\text{-}\alpha_8)] + [\beta_1 Ln(X_{1cons}/X_{1conv}) + \beta_2 ln(X_{2cons}/X_{2conv}) + \beta_3 Ln(X_{3cons}/X_{3conv}) + \beta_4 Ln(X_{4cons}/X_{4conv}) + \beta_5 Ln(X_{5cons}/X_{5conv}) + \beta_6 Ln(X_{6cons}/X_{6conv})] + \beta_7 Ln(X_{7cons}/X_{7conv})] + \beta_8 Ln(X_{8cons}/X_{8conv})] + [u_{cons} - u_{conv}] \quad \dots(5)$$

The left-hand side of the equation gives the total system productivity difference. The natural logarithm of the ratio of per hectare output of conservation practices to that of conventional practices is approximately a measure of the percentage difference in their output.

The first bracketed term on the right-hand side, the difference between the natural logarithms of the constant terms, is the gap attributable to the neutral component of the technology. It is a measure of the neutral technology gap.

The second bracketed term is the gap attributable to the non-neutral component of the technology by input use for conventional cultivators. That is a measure of the non-neutral technology gap after adjusting for the level of input use in the two practices.

The third bracketed term refers to the gap attributable to the difference in input use by the slope coefficient of the productivity function fitted for conservation cultivators. It is the gap in input use between conservation and conventional farmers after adjusting for the production elasticities of different input.

The last component is the random error term, which the model could not consider (Bisaliah 1977; Feder and O'Mara 1981).

We perform an overall regression analysis with the F-test to measure the changes between conventional and conservation farmers. If there are *n* data points to estimate the parameters of both models, one can calculate the F-statistic thus:

$$F = \frac{(RSS1 - RSS2)/(p2 - p1)}{(RSS2/n - p2)}$$

Where, RSS_i is the residual sum of squares of model *i*.

If the regression model has been calculated with weights, replace RSS_i with χ^2, the weighted sum of squared residuals. Under the null hypothesis that Model 2 does not provide a significantly better fit than Model 1, F will have an F distribution, with (p_2–p_1, n–p_2) degrees of freedom. The null hypothesis is rejected if the F calculated from the data is greater than the critical value of the F-distribution for some desired false-rejection probability (e.g. 0.05). The F-test is a Wald test.

Results

At the study location, the farm families that practise conservation agriculture incorporate crop residue or debris (particularly paddy straw, plant of dolichos bean, mustard, lentil and jute) in the field, but not the farm families that practise conventional farming. They feed their crop residue to their livestock and sell the surplus production. The productivity of the winter rice, dolichos bean, mustard, and lentil crop is higher in the conventional farming system (Table 3). However, practising conservation agriculture would restore soil fertility in the Lower Gangetic Plains of West Bengal in one or two years and conserve natural resources. Sustaining the overall agricultural production scenario will take time, and the good and positive effects of conservation agriculture may be expected in the long run.

Economic impact assessment of conservation agriculture

We compare the economic impact of conservation agriculture and conventional farming by fitting multiple regression models. We consider the various system input factors and REY for both farming situations to find out the significant changes, if any. To measure the actual change in crop productivity per hectare we calculate the geometric mean level of various inputs and REY under both farming systems.

Geometric mean levels of system input use and REY under conservation and conventional farming

Compared to conservation agriculture, conventional agriculture uses less of some inputs—6.18% less of seeds, 19.38% less of organic manure, and 33.65% less of irrigation—and conservation agriculture with minimum tillage operation uses 65.52% less of machine

Table 3 Average crop productivity (kg/ha) and residual yield (kg/ha)

Farming type	Winter rice	Dolichos bean	Mustard	Lentil	Summer rice	Jute
Conservation	3,829	26,194	2,394	1,231	6,855	2,928
	(5,513)	(39,290)	(115)	(1,477)	(9,597)	(14,639)
Conventional	4,498	40,907	2,533	1,237	5,602	2,615
	(7,663)	(61,361)	(150)	(1,485)	(7,811)	(13,077)
Pooled	4,163	33,550	2,464	1,234	6,229	2,772
	(6,588)	(50,326)	(132)	(1,481)	(8,704)	(13,858)

Note: Figures in parentheses represent the respective crop residue yield (kg/ha) labour than conservation agriculture and 90.14% less of bullock labour. The system REY per hectare under conservation farming was found to be 2.4% higher than under conventional practices (Table 4 and Figure 1). These findings suggest that practising conservation agriculture in the Lower Gangetic Plains of West Bengal would lead to the long-term sustainability of crop production.

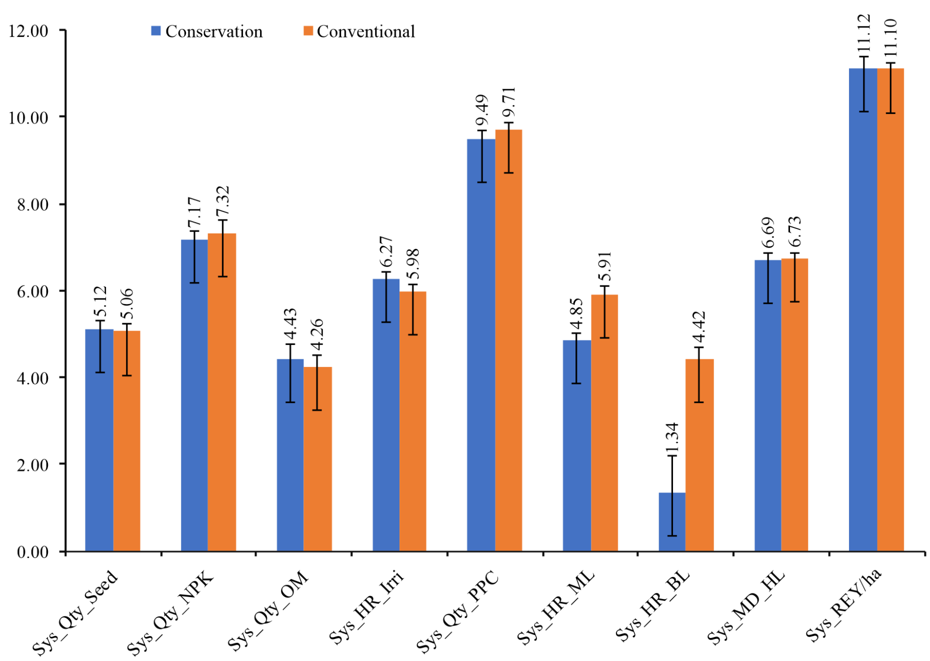
Comparative economics of conservation and conventional agriculture

The system cost of cultivation was 14.46% less per hectare under conservation agriculture than under conventional farming (Table 5), but the net return was 11.15% higher and the return per rupee investment 12.88% higher.

Table 4 Geometric mean levels of SREY and input use

Particulars	Conservation farming	Conventional farming	Relative change(%)
No. of observations	20	20	-
System quantity seed (kg/ha)	168	158	6.18
System quantity NPK (kg/ha)	1,306	1,520	–14.10
System quantity organic manure (q/ha)	85	71	19.38
System irrigation (hour/ha)	529	396	33.65
System quantity PPC (g/ml/ha)	13,245	16,573	–20.08
System machine labour (hour/ha)	128	370	–65.52
System bullock labour (pair-hour/ha)	8	84	–90.14
System human labour (person-days/ha)	808	839	–3.76
SREY (kg/ha)	67,844	66,256	2.40

Note: SREY: System rice equivalent yield



Note: Sys_Qty_Seed: System Quantity Seed used, Sys_Qty_NPK: System Quantity NPK used, Sys_Qty_OM: System Quantity Oragnic Manure used, Sys_HR_Irri: System Irrigation Hour used, Sys_Qty_PPC: System Quantity Plant Protection Chemicals used, Sys_HR_ML: System Machine Labour Hour used, Sys_HR_BL: System Bullock Labour Pair Hour used, Sys_MD_HL: System Human Labour used in Man-days, Sys_REY/ha: System Rice Equivalent Yield ha^{-1}

Figure 1 Logarithmic transformed value of various input use and system productivity per hectare (*$p < 0.05$*)

Table 5 Comparative economics of conservation and conventional agriculture

Farming situation	SREY (kg/ha)	System cost of cultivation (INR/ha)	System gross return (INR/ha)	System net return (INR/ha)	Return per rupee of investment
Conservation	67,844	421,940	910,437	477,032	2.16
Conventional	66,256	493,279	942,912	429,165	1.91
Relative change (%)	2.40	–14.46	–3.44	11.15	12.88

Note: SREY: System rice equivalent yield

Comparative study on regression estimates of conservation and conventional farming situations

The F-statistics appear to be greater than the critical value, indicating a significant difference between conservation and conventional farming practices (Table 6). Conducting a regression analysis of conservation and conventional farming practices separately would help to estimate the changes in input use and system productivity. The pooled analysis reveals that human labour utilization contributed significantly to overall changes in system productivity, and significantly and positively impacts conservation agriculture farm households too, where the F-statistics was found to be significantly higher. In conventional farming situations, the effect of inputs on system productivity gain was non-significant, but the effect of the intercept was significant in both situations. The soil in this region is fertile, and even when no input was applied, some initial gain in productivity is indicated by the pooled analysis; and it is due to the significant impact of neutral technology on the overall change in system productivity under the two situations (Table 6).

Decomposition analysis of total change in input use and system productivity between conservation and conventional cultivators

We decompose the system output change resulting from differences in technology and input use (Table 7). The productivity change in conservation agriculture over conventional farming is estimated at 2.37%; the actual

Table 6 Regression estimates of various input coefficients for conservation and conventional farm households

Particulars	Parameters	Conservation farm households	Conventional farm households	Pooled
No. of farm households	N	20	20	40
Intercept	a	3.89**	9.00*	6.31**
System quantity seed (kg/ha)	X_1	–0.24	0.04	–0.19
System quantity NPK (kg/ha)	X_2	0.17	–0.21	–0.02
System quantity organic manure(q/ha)	X_3	–0.12	0.08	–0.04
System irrigation (hour/ha)	X_4	–0.11	0.30	0.14
System quantity PPC (g/ml per l/ha)	X_5	–0.07	–0.22	–0.04
System machine labour (hour/ha)	X_6	–0.10	0.06	–0.29
System bullock labour (pair hour/ha)	X_7	–0.02	–0.06	–0.02
System human labour (person-days/ha)	X_8	1.45**	0.49	1.09**
Dummy variable for pooled analysis		–	–	–0.33
Coefficient of multiple determination	R^2	0.94	0.48	0.65
Adjusted R square	R^2	0.90	0.11	0.55
F value (p = 0.05)	F	21.62	0.34	6.32
F critical (p = 0.05)	F	2.95	2.95	2.21

Note: * ** significant at p = 0.05 and p = 0.01 respectively

Table 7 Actual and estimated system productivity change

Particulars		Difference between conservation and conventional practices (%)
I)	Total observed difference in system productivity (kg/ha) between conservation and conventional practices	2.40
1)	Due to technology difference	0.49
a)	Neutral technological gap	–511.60
b)	Non-neutral technological gap	512.10
2)	Gap attributable to relative change in input use level weighted by the slope coefficient of productivity function	1.87
a)	Seeds	–1.43
b)	NPK fertilizer	–2.63
c)	Organic manure	–2.17
d)	Irrigation	–3.19
e)	Plant protection chemicals	1.68
f)	Machine labour	10.29
g)	Bullock labour	4.87
h)	Human labour	–5.53
II)	Total estimated difference in system productivity (kg/ha) between conservation and conventional farming practices	2.37

change was found to be 2.40%. That means our model fits well and represents the farming situation of the entire study location. However, the estimated change is segregated into technological differences and subsequent relative change in input use. The overall change is attributed to the relative change in input use weighted by the slope coefficient of the productivity function. The impact of technology was negligible, as the neutral and non-neutral technological change supersede each other and nullify the effect on output. The use of machine labour and bullock labour had a significant, positive impact on the overall changes (Table 7).

Discussion

Farmers who practise conservation agriculture incorporate crop residue in the field and they use less of tillage operations, machine labour, bullock labour, and human labour. Less machine trafficking improves the organic matter, nutrient dynamics, and microbiological and physiochemical properties of the soil and, ultimately, enhances crop growth (Ram et al. 2013; Dass et al. 2017). The change in system productivity observed in our study is 2.40%; the estimated change (2.37%) almost coincided with the observed change, proving a good fit of the regression model (Table 7).

The various treatments under conservation agriculture can reduce system cost and improve input use, crop productivity, and the farm economy. This finding is supported by prior studies (Wang et al. 2016). The beneficial effect of crop residue retention is attributable to better temperature modulation and crop protection from heat stress (Choudhary et al. 2018). Residue retention improves the soil water holding capacity by increasing the soil organic carbon in loam or silt loam soils, which partly explains the difference in the effect of conservation agriculture and conventional practices (Paul et al. 2014). Soil water content—higher under conservation agriculture practices—may play a key role in sustaining soil function during short-term dry periods (Liu et al. 2014).

Conservation agriculture practices raise the water content of the soil, lower its surface temperature, and reduce the uptake of nutrients—especially phosphorus and potassium—and, thereby, the requirement of inorganic fertilizer; these practices use more of organic manure (Das et al. 2014). These practices also less of plant protection chemicals, because the incidence of pests and diseases is lower. Scopel et al. (2013) observe that crop health does not deteriorate under conservation agriculture; our study tends to support the claim. However, our results show that the undisturbed incorporation of soil and crop residue raises the incidence of pests and diseases, and it contradicts previous studies (Kesavan and Malarvannan 2010; Basch et al. 2015; Craheix et al. 2016; Garbach et al. 2016). Our finding holds mainly in young, not-yet-mastered systems, in which the principles of conservation agriculture are not completely or well applied (Scopel et al. 2013).

The productivity of winter paddy, dolichos bean, mustard, and lentil was less for the sample conservation farm households than for the conventional farms. At the initial stages of implementation, the effect of the change in technology on the change in system productivity is marginal (0.49%). The negative impact of neutral technological change under constant returns to scale was superseded by the positive impact of the non-neutral technological change under varying returns to scale of all inputs used. However, the overall change in system productivity was guided by the gap attributable to the relative change in input use weighted by the slope coefficient of the productivity function (1.87%), where the positive impact of machine labour, bullock labour, and plant protection chemicals were observed in conservation agriculture farming systems (Table 7).

Pittelkow et al. (2015) estimate the yields under conservation agriculture to be 2.5% lower than those of conventional practices, and other researchers (Giller et al. 2009; Gilbert 2012) consider that because the yield benefits of conservation agriculture are not immediate, global and widespread uptake is constrained. These findings contradict the scientific estimate that conservation agriculture would raise crop yield by 20–120% (Kesavan and Malarvannan 2010; Basch et al. 2015). But the benefits of conservation agriculture are not instant (Thierfelder and Wall 2012); as Scopel et al. (2013) stress, it may take a few years for soil evolution and ecological equilibrium to take place, and for farmers to gain experience, and for conservation agriculture to demonstrate its potential for augmenting crop yield.

Farms practising conservation farming averaged a 12.88% higher return per rupee of investment than conventional farms. Hence, conservation agriculture impacts the overall socio-economic status of the farming community as well.

Conclusions

Many studies have been conducted worldwide on the long-term sustainability of conservation agriculture, including in the Indo-Gangetic Plains of India. These studies focus on soil health and ecological resources, on which long-term agricultural productivity depends. However, the economic impact of conservation agriculture on the overall farming community needs to be assessed, too, with spatial and temporal multi-analytical diverse approaches.

This study undertakes the spatial approaches of econometrics and cost–benefit analysis to determine the impact of conservation agriculture on the farming community and its difference from conventional farming situations. Conservation agriculture practices aid crop residue retention and minimum soil disturbance, and these use less of inputs, human labour, and machinery; ultimately, therefore, the system cost is less. The results of this study show that, overall, the farm economy improves significantly under conservation agriculture.

However, there is a need to assess conservation agriculture over time in a long-run perspective using a temporal analytical methodology, too. The constraints to adopting conservation agriculture should also be assessed subsequently.

References

Abrol, I P, and S Sangar. 2006. Sustaining Indian agriculture-conservation agriculture the way forward. *Current Science* 91(8). https://www.researchgate.net/publication/228360697_Sustaining_Indian_agriculture_-_Conservation_agriculture_the_way_forward

Basch, G, T Friedrich, A Kassam, and E Gonzalez-Sanchez. 2015. Conservation agriculture in Europe. In: Farooq, M, Siddique, K HM (Eds.), Conservation Agriculture. Springer International Publishing, Switzerland, 357–388. https://core.ac.uk/download/pdf/62467309.pdf

Bhan, S, and U K Behera. 2014. Conservation agriculture in India – Problems, prospects and policy issues.

International Soil and Water Conservation Research 2(4): 1–12. https://doi.org/10.1016/S2095-6339(15)30053-8

Bisaliah, S. 1977. Decomposition analysis of output change under new production technology in wheat faming: Some implications to returns on investment. *Indian Journal of Agricultural Economics* 32(3): 193–201. https://ideas.repec.org/a/ags/inijae/268536.html

Bolliger, A, J Magid, T J C Amado, F Scora Neto, M D F Dos Santos Ribeiro, A Calegari, R Ralisch, and A De Neergaard. 2006. Taking stock of the Brazilian 'zero-till revolution': a review of landmark research an farmers' practice. *Advances in Agronomy* 91: 47–110. https://doi.org/10.1017/S1742170513000550

Cassman, K G, and P L Pingali. 1995. Extrapolating trends from long-term experiments to farmers' fields: the case of irrigated rice system in Asia, In: Barnett, Payne and Steiner (Eds.), Agricultural Sustainability: Economic, Environmental and Statistical Considerations. John Wiley & Sons Ltd., UK, 63–84.

Chatterjee, S, S Banerjee, K L Murmu, and P Bandopadhyay. 2015. Extent of Technological Change in Paddy Cultivation over Eastern Region of India during last four decades. *Visual presentation made in 29th International Conference of Agricultural Economics (ICAE 2015).* Milan, Italy, 8–14 August 20.https://ideas.repec.org/p/ags/iaae15/211459.html

Choudhary, A K, and V K Suri. 2018. System of rice intensification in promising rice hybrids in north-western Himalayas: crop and water productivity, quality, and economic profitability. *J. Plant Nutr.* 41: 1020–1034 . https://doi.org/10.1080/01904167.2018.1431675

Craheix, D, F Angevin, T Doré, and S de Tourdonnet. 2016. Using a multicriteria assessment model to evaluate the sustainability of conservation agriculture at the cropping system level in France. *European Journal of Agronomy* 76: 75–86. https://hal-agroparistech.archives-ouvertes.fr/hal-01354938/document

Das, A, R Lal, D P Patel, R G Idapuganti, J Layek, S V Ngachan, P K Ghosh, J Bordoloi, and M Kumar. 2014. Effects of tillage and biomass on soil quality and productivity of lowland rice cultivation by small scale farmers in North Eastern India. *Soil and Tillage Research,* 143: 50–58. http://dx.doi.org/10.1016/j.still.2014.05.012

Dass, A, K Shekhawat, A K Choudhary, S Sepat, S S Rathore, G Mahajan, and B S Chauhan. 2017. Weed management in rice using crop competition-a review. *Crop Protection* 95: 45–52.

https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2Fj.cropro.2016.08.005

Dawe, D A, P Dobermann, S Moya, P Abdulrachman, S Y Lal, B Li, G Lin, OPanaullah, Y Sariam, A Singh, P S Swarup, and Q X Zhen Tan. 2000. How widespread are yield declines in long-term rice experiments in Asia? *Field Crops Research* 66: 175–193.

https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2FS0378-4290(00)00075-7

Department of Planning and Statistics, Government of West Bengal. 2013–14. District Statistical Handbook, Nadia.

Ekboir, J, K Boa, and A A Dankyii. 2002. The impact of no-till in Ghana. In: L. Garcia-Torres, J. Benites, A. Martinez-Vilela and A. Holgado-Cabrera(Eds.), Conservation Agriculture: A Worldwide Challenge, 757–764. Cordoba, Spain: ECAF/FAO.

Erenstein, O. 2009. Specification effects in zero tillage survey data in South Asia's rice-wheat systems. *Field Crops Research* 111(1–2): 166–172. https://doi.org/10.1016/j.fcr.2008.12.003

Erenstein, O, and V Laxmi. 2008. Zero tillage impacts in India's rice-wheat systems: a review. *Soil and Tillage Research* 100(1–2): 1–14. https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2Fj.still.2008.05.001

Erenstein, O, K Sayre, P Wall, J Hellin, and J Dixon. 2012. Conservation agriculture in maize- and wheat-based systems in the (Sub)tropics: lessons from adaptation initiatives in South Asia, Mexico, and Southern Africa. *Journal of Sustainable Agriculture* 36(2): 180–206. https://doi.org/10.1080/10440046.2011.620230

FAO. 2012. Food and Agriculture Organization of the United Nations, Agriculture and Consumer Protection Department, Conservation. http://www.fao.org/conservation-agriculture/en/

Feder, G, O' Mara, and T Gerald. 1981. Farm size and the adoption of green revolution technology. *Economic Development and Cultural Change* 30: 59–76. https://www.jstor.org/stable/3203155

Flinn, JC, and S K De Datta. 1984. Trends in irrigated rice yields under intensive cropping at Philippines research stations. *Field Crops Research* 5: 201–216. https://doi.org/10.1016/0378-4290(84)90002-9

Garbach, K, J C Milder, F A J DeClerck, M Wit de Montenegro, L Driscoll, and B Gemmill-Herren. 2016. Examining multi-functionality for crop yield and ecosystem services in five systems of agroecological intensification. *Int. J. Agric. Sustain* 5903: 1–22. https://doi.org/10.1080/14735903.2016.1174810

Gilbert, N. 2012. Dirt poor: the key to tackling hunger in Africa is enriching its soil. The big debate is about how to do it. *Nature* 483: 525–527. https://www.nature.com/news/african-agriculture-dirt-poor-1.10311

Giller, KE, E Witter, M Corbeels, and P Tittonell. 2009. Conservation agriculture and smallholder farming in Africa: the heretic's view. *Field Crops Res.* 114: 23–34. https://doi.org/10.1016/j.fcr.2009.06.017

Govaerts, B, N Verhulst, A Castellanos-Navarrete, K D Sayre, J Dixon, and L Dendooven. 2009. Conservation agriculture and soil carbon sequestration: between myth and farmer reality. *Critical Reviews in Plant Sciences* 28: 97–122. https://doi.org/10.1080/07352680902776358

Greenlands, D L. 1997. The Sustainability of Rice farming, CAB International (UK) and International Rice Research Institute, Manila, Philippine, 115. http://books.irri.org/0851991637_content.pdf

Gupta, R K, and A Seth. 2007. A review of resource conserving technologies for sustainable management of the rice-wheat cropping systems of the Indo-Gangetic Plains (IGP). *Crop Protection* 26(3): 436–447. https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2Fj.cropro.2006.04.030

Gupta, R K, R K Naresh, P R Hobbs, Z Jiaguo, and J K Ladha. 2003. Sustainability of post-green revolution agriculture: The rice-wheat cropping systems of the Indo-Gangetic Plains and China. In *Improving the Productivity and Sustainability of Rice-wheat Systems: Issues and Impacts* 7: 149–171. https://www.scirp.org/(S(351jmbntvnsjt1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=1565078

Haggblade, S, and G Tembo. 2003. Conservation Farming in Zambia: EPTD Discussion Paper No 108. Washington DC, IFPRI.

https://www.researchgate.net/profile/Steven_Haggblade/publication/5056041_Conservation_Farming_in_Zambia/links/576c688808aedb18f3eb2905/Conservation-Farming-in-Zambia.pdf

Hobbs, P R, and B Govaerts. 2010. How conservation agriculture can contribute to buffering climate change. In: M P Reynolds(Ed), *Climate Change and Crop Production*, CAB International, 177–199. http://dx.doi.org/10.1079/9781845936334.0177

Kesavan, PC, and S Malarvannan. 2010. Green to evergreen revolution: ecological and evolutionary perspectives in pest management. *Curr. Sci.* 99: 908–914. https://www.researchgate.net/publication/289328651_Green_to_evergreen_revolution_Ecological_and_evolutionary_perspectives_in_pest_management

Kumar, A, and D S Yadav. 2001. Long-term effects of fertilizers on the soil fertility and productivity of a rice-wheat system. *Journal of Agronomy and Crop Science* 186 (1): 47–54. DOI: 10.1046/j.1439-037x.2001.00452.x

Liu, C, M Lu, J Cui, B Li, and C Fang. 2014. Effects of straw carbon input on carbon dynamics in agricultural soils: a meta-analysis. *Global Change Biology* 20: 1366–1381. https://doi.org/10.1111/gcb.12517

Nambiar, K K M. 1988. Annual reports, long-term fertilizer experiments in India. IARI, New Delhi, India. 1971–-988.

Patzek, T W. 2008. Thermodynamics of agricultural sustainability: the case of US maize agriculture. *Critical Reviews in Plant Sciences* 27(4): 272–293. https://doi.org/10.1080/07352680802247971

Paul, J, A K Choudhary, V K Suri, A K Sharma, V Kumar, and Shobhna. 2014. Bioresource nutrient recycling and its relationship with biofertility indicators of soil health and nutrient dynamics in rice-wheat cropping system. *Commun. Soil Sci. Plant Anal.* 45: 912–924. https://doi.org/10.1080/00103624.2013.867051

Pingali, P L, M Hossain, and R Gerpacio. 1997. Asian Rice Bowls: The Returning Crisis? CAB International IRRI, Los Banos, Philippines. http://books.irri.org/0851991629_content.pdf

Pittelkow, CM, X Liang, Ba Linquist, K J van Groenigen, J Lee, M E Lundy, N van Gestel, J Six, R T Venterea, and C van Kessel. 2015. Productivity limits and potentials of the principles of conservation agriculture. *Nature* 517: 365–368. https://doi.org/10.1038/nature13809

Ram, H, Y Singh, K S Saini, D S Kler, and J Timsina. 2013. Tillage and planting methods effects on yield, water use efficiency and profitability of soybean-wheat system on a loamy sand soil. *Experimental Agriculture* 49: 524–542. http://dx.doi.org/10.1017/S0014479713000264

Scopel, E, B Triomphe, F Affholder, F A MDa Silva, MCorbeels, J H V Xavier, RLahmar, S Recous, M Bernoux,E Blanchart, I De Carvalho Mendes, and S De Tourdonnet. 2013. Conservation agriculture cropping systems in temperate and tropical conditions, performances and impacts. A review. *Agron. Sustain. Dev.* 33: 113–130. https://doi.org/10.1007/s00374-007-0165-2

Singh, Upma, K Anil Choudhary, and Shilpi Sharma. 2020. Comparative performance of conservation agriculture vis-a-vis organic and conventional farming, in enhancing plant attributes and rhizospheric bacterial diversity in Cajanus cajan: A field study. *European Journal of Soil Biology* 99: 1–10. https://doi.org/10.1016/j.ejsobi.2020.103197

Thierfelder, C, and P C Wall. 2012. Effects of conservation agriculture on soil quality and productivity in contrasting agro-ecological environments of Zimbabwe. *Soil Use and Management* 28(2): 209–220.https://doi.org/10.1111/j.1475-2743.2012.00406.x

Timsina, J, and D J Connor. 2001. Productivity and management of rice-wheat cropping systems: Issues and challenges. *Field Crops Research*69(2): 93–132. https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2FS0378-4290(00)00143-X

Verhulst, N, B Govaerts, E Verachtert, A Castellanos-Navarrete, M Mezzalama, P C Wall, A Chocobar, J Deckers, and K D Sayre. 2010. Conservation agriculture, improving soil quality for sustainable production systems. In *Advances in Soil Science: Food Security and Soil Quality,* 137–208 (Eds R. Lal and B. A. Stewart). Boca Raton, FL, USA: CRC Press

Wall, P C. 2007. Tailoring conservation agriculture to the needs of small farmers in developing countries: an analysis of issues. *Journal of Crop Improvement* 19(1–-): 137–155. https://www.tandfonline.com/doi/abs/10.1300/J411v19n01_07

Wall, P C, C Thierfelder, A Ngwira, B Govaerts, I Nyagumbo, and F Baudron. 2013. Conservation agriculture in Eastern and Southern Africa. In: Conservation Agriculture: Global Prospects and Challenges (Eds R. A. Jat, K. L. Sahrawat and A. H. Kassam). UK: CABI.

Wang, Z, L Liu, Q Chen, X Wen, and Y Liao.2016. Conservation tillage increases soil bacterial diversity in the dryland of northern China. *Agron. Sustain. Dev*. 36: 1–9 .https://link.springer.com/article/10.1007/s13593-016-0366-x

Wolff, P, and T M Stein. 1998. Water efficiency and conservation in agriculture – opportunities and limitations. *Agriculture and Rural Development* 5(2): 17–20. https://www.sciencedirect.com/science/article/pii/S2095633915300538

Yadav, R L, B S Dwivedi, and P S Pandey. 2000. Rice-wheat cropping system: assessment of sustainability under green manuring and chemical fertilizer inputs. *Field Crops Research* 65: 15–30. https://www.researchgate.net/publication/222025407_Rice-wheat_cropping_system_Assessment_of_sustainability_under_green_manuring_and_chemical_fertilizer_inputs

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Moving towards an implementable agenda for the rural economy of Gujarat

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Abstract The farm laws enacted in 2020 plan a transformation towards modernization, but the organizational forms of the new agriculture, which are important for this transformation, will involve thinking in collectives and addressing information concerns and stakeholder requirements. These alternate paths for rural development—apart from government projects, involving huge outlays and, often, high welfare losses—will enable a movement towards the modernization of agriculture that is not biased or based on heavy expenditure on inputs. However, the scope for agricultural growth in Gujarat is constrained by the stable, unchanging village hierarchy and the hardiness and practicality of farmers.

Keywords Rural economy, policies, institutions, markets

JEL codes P32

The basic premise of this paper is that the performance of Gujarat's rural sector requires last-mile delivery in terms of inputs to farmers and effective farm field productivity enhancement. Such enhancement must be backed by storage, sale, trade, and transport and by growth in the non-farm sector. Such enhancement and growth will be led by implementable innovative practices suited to rural Gujarat. Cooperatives must facilitate loans and insurance and identify farmers eligible for government support services like irrigation and technology provision. Optimal support in these respects will obviate or minimize the requirement of top-level interventions like subsidy or price ceiling.

The government machinery is often influenced by interests and inaction. According to government pamphlets, organic farming, horticulture, micro irrigation, etc. are good options for technological progress and overall development of agriculture, but many farmers are left high and dry by such arrangements and prefer to supply directly to processors, as the author found in official interactions with academics and extension officers as held at Vallabh Vidyanagar[1] sponsored by the Government of Gujarat. There are gaps in coordination or in the flow of information among stakeholders—farmers, government, nongovernmental organizations (NGO) and state agricultural universities (SAU)—but the government machinery does not provide any solutions in that direction; instead, it alludes to the government subsidy on cold storage and electricity, and holds that good infrastructure and would be a win-win proposition for farmers.

We state the need for increasing the target group of such support services, state challenges in that regard, and suggest solutions. Specifically, unequal distribution of land, water, as well as added value is deeply entrenched (Aubron 2015) in the state in terms of social relations of dependency. Milk cooperatives provide everyone in the plains access to dairy farming and poor rural families the means for gaining upward social mobility, as do subsidies or loans for irrigation.

[1] 'Doubling Farmer Income', a workshop held on 1–2 June 2018 at B A College Auditorium Hall, Anand Agriculture University Campus, Anand, Gujarat.

Base-level scenario and challenges

A major conclusion of this author's study (Alagh 2014) of Gujarat's agricultural marketed surplus is that agricultural trade is mostly privately handled, and this is a severe limitation in transforming rural Gujarat. The report gave results on the relevant variables leading to market surplus—including cropping and irrigation intensity, fertilizer and electricity consumption, uses of modern agricultural implements, etc.—and these make for an agricultural miracle.

The piece-based implemented agenda in rural Gujarat has been effective, and it has accelerated agricultural development in the state after the 2000. The agenda has specific plans: the Krishi Mahostav campaign (for research and extension support); Soil Health Card facilities (for soil conservation); the Jyotigram Yojana (to supply electricity round the clock); the Sardar Sarovar Project (for constructing major and medium canals for irrigation); and Sardar Patel Sahakari Jal Sanchaya Yojana (for managing groundwater irrigation). Other policies include programmes to develop horticulture (through the Gujarat Horticulture Mission) and improve market access (through Agricultural Produce Marketing Committees (APMC) and farmer producer companies (FPC)) (Behera 2015).

The sources of surface water irrigation are the major and medium irrigation canals under the Sujalam Suphalam Yojana; minor irrigation schemes and indirect benefits through percolation tanks; and check dams, etc. under the Sardar Sarovar Project Yojana, which need to reach marginal farmers. The dynamic water resources development department of the Government of Gujarat estimates the utilization and irrigation potential of surface water and groundwater sources. However, the delivery system, constrained by the panchayats at the village level and by the state bureaucracy, is not balanced or equitable (Acemoglu et al. 2005), and the results depend on how motivated the bureaucracy is in handling these issues.

The bureaucracy is inactive, and the political will for action is missing, because the problems—like the moneylender/trader trap and the inadequate solutions to the problem of conditions for crop sale—need long-term solutions, which do not interest politicians or the bureaucracy. If mutual trust between particular individuals were elevated to institutional arrangements, where the necessary externalities are taken care of, the parties to a contract could trust each other, and there would be little possibility of default (Hayami 1997: 246). As a member of a cooperative, the consumer would have access to the modern financial system of credit, and they would derive better utility and be better off. If the constraints of the bureaucracy are overcome, society focuses on institutions, and more effective channels of communication between farmers and the government are instituted, clarity will emerge in terms of responsibility allocation and results (North 1992).

Growth theorists (Romer 1986; Barro et al. 1995) hold that for growth to be stable and sustainable, certain conditions must be met: the workforce must be skilled, economic activities must be efficient, and there should be innovations of knowledge systems and learning and experience effects of skilled stakeholders. In Gujarat the nature of rural employment is based on the nature of the farmer as an innovator and as an enterprising risk taker within constraints, which are the Gujarati traits.

The soil and weather conditions are difficult in certain areas, and expanding government extension mechanisms (Schultz 1964) there and concerted and focused action would improve the input supply and extension arrangement, make it intensive, and spread it out well regionally. Water harvesting and farm field irrigation are innovative concepts capable of generating a lot of social and economic benefits in water-rich regions (Ilyas 1999), but these do not work in naturally water-scarce regions like Saurashtra, where the soils absorb less moisture. The surplus water of the Narmada can be transferred to North Gujarat, and it can be used to recharge the alluvial aquifers by the means of gravity recharge and spreading water in the fields, as some scholars have argued recently; and the initial analysis has shown that this would be economically viable (Ranade 2004), but correct pricing would be crucial.

In Gujarat, the yield of staple crops, like wheat, and of commercial crops, including horticultural crops, improved between 2002 and 2007, influenced by massive growth in the net irrigated area and gross irrigated area and by the increase in the ratio of gross irrigated area to gross cropped area, the ratio of net irrigated area to net sown area, and the percentage of the area under food crops and non-food crops. Extension is less visible in areas where soil, water, or rainfall conditions are poor. One area where extension seems to be missing is the Panchmahal district. Here, the monsoon is adequate at best—rainfall averages 700–800 mm—and long dry spells are common even in the rainy season.

In an interview, a farmer[2] said that they do not have a power connection for their tube well, and that is a problem at the time of irrigation. The Sardar Sarovar Project water though flowing through this area is not reaching the village as it is uphill from the canal distributary. Extension officers do little work, but there is much publicity, and government agencies provide seeds and fertilizers, but other problems remain, like wild pigs and nilgais eating the crop.

The cost of 'getting things done' increases depending on the size of the requirement. The price of agricultural labour has increased four times due to the factory nearby. The sale of the crop was dominated by the trader, unlike in Bavla and Unjha, where well-oiled APMCs function. Even the storage godown of the APMC was registered in the name of the local trader, who doubles as the government intermediary, something that should not happen—but anything goes when there are no checks or balances. The farmer felt that Digital India had made things worse—illiterate farmers cannot fill electronic applications, and the bureaucracy has set in deeper because they serve as an intermediary.

In years of low rainfall, agents delay procurement, and farmers have no choice but to sell their harvest at a price much lower than agreed; to avoid this outcome, potato producers in Gujarat have shifted from contract farming to non-contract farming. Farmers assume that the cost of production in contract farming is high. The system of contract farming in Gujarat is tripartite; the APMC acts as facilitator.

The policy analysis of Klein and Tinbergen (Alagh 2004) with regard to instruments of large projects in rural infrastructure and implementable checks on results needs to include marginal farmers and a range of alternative stakeholders / institutions in its fold. Other features of working towards a balanced model of agricultural development ensure equity and promote efficiency.

The system in rural Gujarat depends largely on the inherent strength of the stable yet unchanging village hierarchy and the hardiness and practicality of farmer, and these same factors constrain (Pattnaik and Shah 2013) the ability of society at large to take firm, resolute steps towards an actionable agenda—without the farmer needing to look over their shoulder.

Studies suggest that commercialization will lead to quick transformation (Nadkarni 1988), but the danger is that the paradigm shift (Pal et al. 2008) involves corporatization. The organizational forms of the new agriculture, which are important for this transformation, will involve thinking in collectives (Agarwal 2010) and as groups. The literature on new forms of organization (Singh 2012) addresses value addition across the value chain.

The institutional framework of SAUs, etc. already exists in Gujarat. To this effect some field case studies by the author from 2011 to 2017 are described as an illustration of the problématique and possible solutions. The hope is that the combining of sustainability and efficiency as one goal is swift and alternate paths for commercialization, apart from corporate linkages, are generated. These alternate paths for rural development—apart from government projects, involving huge outlays and, often, high welfare losses—will enable a movement towards modernization of agriculture which is not biased or based on heavy expenditure on inputs.

Holistic solutions

Nowadays, the term 'rural development' is used in a holistic sense, and it takes into account the industrialization and tertiarization of rural spaces, infrastructure, markets, and the social and economic well-being of the rural poor. These alternate mechanisms include the complex policy option (Birthal et al. 2007) of making rural areas the focus of diversified enterprise, and transformation involves extending the benefits of development to the poorest among those who seek a livelihood in rural areas, such as small-scale farmers, tenants, and the landless. For rural institutions to function well across the board, the necessary condition is for a minimum check on

[2] Hasmukh Parmar owns 40 bigha of land in Derol, a village in Kalol taluka, Panchmahal district, Gujarat. A bigha is a sixth of a hectare; therefore, 40 bighas is nearly 7 hectares.

leakages in terms of delays and disagreements. More enthusiasm for protecting institutions is needed, irrespective of politics; this is a matter of culture, not agriculture.

The Parliament of India enacted new farm laws in 2020; a necessary condition for these laws to be effective is market viability—that is, arrangements for streamlining input use, like global potato contract farming alliances with McCain (Sharma et al. 2013) in Mahesana and the proposed reform of APMC. But the sufficient condition is to settle the fear that the produce of small cultivators is not secure; for instance, in the McCain case, a small potato contract farmer will be challenged by the urge to sell in the open market rather than meet exacting conditions in terms of the shape and size of potatoes.

A long-standing argument in agricultural economics stresses on technology (Rao 1989) rather than shifting away from staples. When agricultural trade is privately handled, a quick advance towards commercialization is de rigueur in the plan for rural transformation (Kannan 2011): the impact of the green revolution technologies has ebbed, as is well documented, and a new epoch in agricultural growth has not been seen after liberalization (Chand 2008).

The clinching argument for modernization, with effective checks, is that small commercial farmers—rather than large-scale farms or poorer, semi-subsistence producers—are the key engines of economic growth and poverty reduction. A significant portion of that impact comes through local general equilibrium effects through labour markets (Mellor 1963) and those farmers' demand for non-tradable goods and services, both of which generate high multiplier effects that concentrate gains among the poor. Hence, imperfections in rural factor and product markets, which are pervasive, can be dealt with (Barret, cited in Mellor 2017)—while staying within modern market mechanisms—and the argument in favour of modernizing the agricultural mandi and introducing commercial contract arrangements thus becomes far more effective. The modernization of staple farm fields can have a significant, positive effect on the marketed surplus ratio, which means that more modernized the agriculture, the greater the inducement for farmers to sell proportionately higher amounts of their crop in the market; these would be farmers taking advantage of modern technology in agriculture and generating larger surpluses to sell.

We suggest a local, ground-up approach (Easterly 2007) that focuses on alternative forms of organizational rural communities—like pani panchayats, self-help groups, village cooperative credit societies, and producer companies. If we envisage that rural organizations in Gujarat should work towards the same objective, we should assess the investment and technology required to remove the uncertainty in rural Gujarat and plan for these. Therefore, to enhance agricultural growth, the Gujarat government needs to combine large, well-directed projects and improve the effectiveness of ground-level monitoring and facilitation.

In the non-farm economy, especially in rural retail, change and advances are taking place fast. There is demand for bottom-of-the pyramid goods, like Newport jeans, which have to be specially procured from the Ahmedabad wholesale market. Kirana stores have transformed themselves into modern, organized over-the-counter stores and systematized their accounts and inventories. Modern retail in rural Gujarat (Dutta & Alagh 2018) compete with nearby kirana stores and have to make efforts to create a space in terms of range and quality of goods because kirana stores offer cheaper alternatives. In field visits to such supermarket-format stores in rural Gujarat, the author found that some retailers spoke of how the villagers had to be trained to shop with a cart, trolley, or basket and pay at the counter, and also of how customers had gradually, albeit hesitatingly, started demanding specific commodities. Store owners spoke of how the distribution and training provided by the central store had helped them become viable.

Conclusions

In Gujarat, as in India, schemes supporting farm acreage growth and public investment have run their course, and the new agricultural policy of 2000 needs to show its effects in faster and more equitable growth. Diversified farm and non-farm enterprises will work in Gujarat if effective credit cooperatives, rural commercial banks, rural retail, rural colleges, roads, storage godowns, and mandis are streamlined and supported. Small business stores—not restricted only to kirana stores, but rural supermarkets in some areas, local milk dairies, tailor shops, commercial banks, small papad factories, or other cottage industries—are seen in Gujarati villages as an extension of urban culture.

As the pace of information flow steps up, NGOs and trusts need to think synergistically. The spread has to be faster. Horticultural projects, online APMCs, micro irrigation, technology in seeds, fertilizers and pesticides, all will work provided the government machinery does not only enforce its will but becomes a more effective facilitator. Success breeds many progenies; so, if policy academics and other rural stakeholders join hands, change can be on the horizon. Top-down arrangements, including contracts and modern enterprises, will work—if the rural stakeholder is empowered by knowledge and their business supported by the government bureaucracy—over time, if not immediately.

References

Acemoglu, D, S Johnson, and J A Robinson. 2005. *Institutions as a fundamental cause of long-run growth*. In: Handbook of Economic Growth, 1, 385–472, North-Holland.

Acemoglu, D. 2012. Introduction to economic growth. *Journal of Economic Theory*, 147(2), 545–550.

Agarwal, B. 2010. Rethinking agricultural production collectivities: the case for a group approach to energize agriculture and empower poor farmers. *East Asian Bureau of Economic Research* No. 22736.

Alagh, M. 2014. Assessment of marketed and marketable surplus of major foodgrains in Gujarat. *Indian Journal of Agricultural Marketing*, 28(2), 60–80.

Alagh, Y K. 2004. Policy without theory: India in a globalising economy. *Economic and Political Weekly*, 39(7), 1748–1753.

Aubron, C, H Lehoux, and C Lucas. 2015. Poverty and inequality in rural India. Reflections based on two agrarian system analyses in the state of Gujarat. *EchoGéo*, 32.

Barrett, Christopher B. 2017. *Agricultural development and economic transformation.* New York: Springer.

Barro, Robert, and X Sala-i-Martin. 2004. *Economic growth.* MIT Press.

Behera, D. 2015. Agricultural development and inclusive growth in India: A case study of Gujarat. *International Journal of Food, Agriculture and Veterinary Sciences* 5(1), 41–52.

Birthal, P S, P K Joshi, D Roy, and A Thorat. 2007. *Diversification in Indian agriculture towards high-value crops*. IFPRI Discussion Paper 00727, International Food Policy Research Institute (IFPRI).

Chand, R. 2008. The global food crisis: Causes, severity and outlook. *Economic and Political Weekly*, 43 (26/27), 115–122.

Dutta, S, and Alagh, M. 2018. *Supermarket for rural customers: a study of a community-oriented social enterprise in Gujarat*, Academic Foundation, New Delhi.

Easterly, W. 2001. *The Elusive quest for growth: Economists' adventures and misadventures in the tropics*. MIT Press.

Hayami, Y, and J P Platteau. 1997. *Resource endowments and agricultural development*: Africa vs. Asia (No. 192).

Ilyas, S M. 1999. Water harvesting towards water demand management and sustainable development. *Journal of Rural Reconstruction*, *32*2, 31–43.

Kannan, K P. 2011. Agricultural development in an emerging non-agrarian regional economy: Kerala's challenges. *Economic and Political Weekly,* 46, 64–70.

Mellor, J W. 1963. The use and productivity of farm family labor in early stages of agricultural development. *Journal of Farm Economics*, 45(3), 517–534.

Nadkarni, M V. 1988. Crisis of increasing costs in agriculture: Is there a way out?. *Economic and Political Weekly*, 23 (39), A114-A119.

North, D. 1990. *Institutions and their consequences for economic performance: the limits of rationality*, 383–401. University of Chicago Press.

Pal, S, P K Joshi, and R Saxena. 2003. *Institutional change in Indian agriculture,* Workshop Proceedings, National Centre for Agricultural Economics and Policy Research, New Delhi.

Pattnaik, I, and A Shah. 2013. *Gujarat's agricultural growth model: how sustainable it is?* International Journal of Agriculture and Food Science Technology, 4, 281–286.

Ranade, R and M Dinesh. 2004. Narmada water for groundwater recharge in North Gujarat: conjunctive management in large irrigation projects. *Economic and Political Weekly,* 39, 3510–3513.

Rao, C H H. 1989. Technological change in Indian agriculture: emerging trends and perspectives. *Indian Journal of Agricultural Economics*, 44(4).

Romer, P. 1986. Increasing returns and long-run growth. *The Journal of Political Economy*, 94(5), 1002–1037.

Schultz, T W. 1964. *Transforming traditional agriculture*. New Haven CT: Yale University Press.

Sharma, V P, B Vorley, A Suleri, L Digal, and J Huang. 2013. *Linking smallholder producers to modern agri-food markets: case studies from South and South-East Asia.* Allied Publishers, New Delhi.

Singh, S. 2012. New markets for smallholders in India: Exclusion, policy and mechanisms, *Economic and Political Weekly*, 95–105.

ABSTRACTS

Growth Drivers transforming Start-ups to potential enterprises: A Multi- Case study of Agri startups

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A multi case study of agri start-ups is aimed to understand the relation between the growth drivers leading to progress in startup life cycle. The higher education levels, prior expertise of managerial team and technological innovation in operations are growth drivers through the ideation, validation and early traction stage while strategic decisions viz., vision, market oriented opportunity switch, expansion strategies and networking derived out of experiences and learning's are major growth drivers in pushing the startups to growth stage. Business strategies, scalability in business operations, gaining investor confidence for regular funding are key growth drivers in case 1 and 2 to attain scale-up stage and case 3 to growth stage. The cases showed a steady annual sales growth and improvement in operational efficiency reflected through asset turnover ratios.

Impact of Covid-19 on the supply chain of apple crop in Jammu and Kashmir, India

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This paper aims to highlight the disruption caused by COVID-19in the supply chain of apple in Jammu and Kashmir, India. The paper studies the impact of COVID-19 on pre-harvesting, harvesting and post-harvesting stages of apple-crop. Primary Data was collected through the telephonic survey. Farmers acknowledged delay in spraying the chemicals and fertilizers, that resulted in increase of pests and weeds. Another group of respondents who had stored last year's produce in Controlled-Atmosphere-Storages (CAS) failed to find any buyer due to closure of the markets and the consequent fall in demand. The transportation and the storage cost of their stored produce is increasing with each passing day, therefore gradually eroding their profitability. Longevity of COVID-19 and the subsequent lockdown will likely impact the harvesting phase of the current apple. Only 3.5 % of the total production of apple can be stored in CAS, thus raising serious concerns regarding the marketing during the pandemic.

A study on agribusiness incubation centres in Telangana

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Efforts are made to understand the structure and functioning of the agribusiness incubators (ABIs) in Hyderabad. A structured questionnaire was framed for collection of data from incubators and incubatees from different ABIs. Based on the primary data and secondary data collected, we analyzed the socio economic profiles of the incubatees from different ABIs. The challenges faced by the agribusiness incubation centres were socio-cultural barriers related to incubatees and human resources, which were considered as the critical challenges faced while administrative issues and competition play insignificant role. Strategies like personal mentoring to the incubatees, focusing on market positioning and linkages, understanding of business environments, entrepreneurial ecosystem, linkage with educational institutes and industry, self-financing of incubators, incubation to the new incubators, networking of incubation centres, usage of technology and information, linking with ELP units of agricultural courses of university set up and going for public-private partnership models, are suggested for the agribusiness incubation ecosystem to function more efficiently.

Ethanol: A saviour of growth

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India's 85% of the petroleum oil need is being met through imports. Indian Government has already mandated blending of ethanol in gasoline by 10% to reduce the oil import. Bureau of Indian Standards is planning for 20% ethanol blended gasoline for use as vehicular fuel in 2022. In this context, the present study aims to analyses the ethanol production potential from sugar cane juice, B and C Molasses, sugar beet, sweet sorghum, cassava, maize, paddy straw and wheat straw. Production of ethanol from sugar cane is comparatively advantage but it purely relies on international price of sugar and oil. Prohibition of liquor will be best alternative option and diversion into ethanol blending programme augment the revenue loss due to it and it will reduce the crude oil demand so appreciate the value of Indian rupees in turn that will reduce the cost of crude oil. Production of ethanol from paddy and wheat straw is viable option to overcome the pollution caused by burning the stubbles.

Future of Indian agriculture: Amendments through farm reforms

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India is a global agricultural powerhouse. It is the world's largest producer of milk, pulses, and spices, and has the world's largest cattle herd (buffaloes), as well as the largest area under wheat, rice and cotton. It is the second largest producer of rice, wheat, cotton, sugarcane, farmed fish, sheep & goat meat, fruit, vegetables and tea. The country has some 195 m ha under cultivation of which some 63 percent are rainfed (roughly 125m ha) while 37 percent are irrigated (70m ha). In addition, forests cover some 65m ha of India's land. The recently announced Agricultural reforms and schemes such as, The Essential Commodities (Amendment) Act, 2020, The Farmers' Produce Trade and Commerce (Promotion & Facilitation) Act 2020, The Farmers (Empowerment and Protection) Agreement on Price Assurance and Farm Services Act 2020, Agriculture Infrastructure Fund and Promotion of Farmer Producer Organizations (FPO) Scheme have created a versatile outreach opportunities to the farmers in various domain of production, finance and marketing as concern. The secondary data base study with the literature inputs from various research bodies and published studies was carried out to know the opinion benchmark about the recent reforms and various schemes. The study concluded that, the reforms through amendments in these agriculture core areas if carried out earnestly could go a long way in helping the farmers get out of the misery and help achieve the goal of doubling of farmer's income in the set time frame and overcome the glitches in agriculture and its allied sectors.

The role of stakeholders in tea value chain and an appraisal of constraints faced by them during COVID-19 crisis

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The present study aims at to identify the important stakeholders (Small tea growers, green tea leaf collector, processor, wholesaler and retailer) of the tea value chain, and constraints faced by them during the COVID-19 pandemic. All the stakeholders of the value chain faced different problem according to their way of operation, among them tea growers faced maximum problem regarding growing of green tea leaves. To identify the important constraints, we used Garrett's ranking technique. The study revealed that, unavailability of inputs on peak plucking time was the main constraint faced by the small tea growers with 75.39 average score in garret ranking. In case of leaf collector, processor and wholesaler/retailers the main problems were restricted transportation (81.66), unavailability of quality tealeaves (77.43) and price instability respectively (85.34).

Life situation indicators contribute more to satisfaction of organic farmers in Indian Himalayan state of Sikkim

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The wellbeing of the farmers matters for the development of the sector as they are at the centre of production process. The state of Sikkim, located at the North Eastern Himalayan region of India, is the first state to be declared as an organic state in 2016 where about 75000 ha of agricultural land are under organic. Hence, this paper was an attempt to understand and quantify the satisfaction derived by the farmers from farming and overall life situation. About 55.71% of the respondents had deficit farm receipts over its basic expenditure which implies that they were not satisfied at farming. Similarly, the self-rating approach also revealed that only 47.14% and 38.57% of the farmers were satisfied at farm input and output indicators, respectively, but when the subjective indicators related to farming were included, about 71.43% farmers were found to be satisfied at farming. Majority of the respondents (80%) were satisfied at their overall life due to their satisfaction at indicators under other life situation dimension. The inner happiness outweighed the shortfall in income.

Value chain analysis of smoked fish in Manipur

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The smoked fish is popular and in high demand in Manipur. In this paper vale chain of smoked fish was analyzed and findings showed that the smoking of fish in Manipur is profitable activity which provides gainful employments to the women in the state. The sub value chain-I(traders outside states-wholesalers-retailers-consumers) and sub value chain-IV(fishermen-fish processor-traders- retailers-consumers) were identified as core value chain through which maximum volume and value flow takes place. The women participation was found to be higher in processing as well as in trading of smoked and other processed fish products. Further, for upgradion of value chain, technical and financial supports are crucial.

Institutional innovation by Bagma Agri- Producer Company Ltd., Tripura – An exploratory research based case study

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The study was carried out to explore the innovation, interest of registered members and their satisfaction level of being members of a multi-product based Farmer Producer's organization located in rural area of the North Eastern State, Tripura. Descriptive analysis was carried out through SWOT analysis and it was observed that the selected FPO namely Bagma Agri Producer Company Limited (BAPC Ltd.) has future opportunities for overall development of concerned farming community. Ordinal Linear Regression estimation considering the level of satisfaction of being member as dependent variable against different socio-economic variables showed that except gender and income from non-farming income didn't showed significant influence on level of satisfaction of being member of BAPC Ltd. Coefficients of other variables were positive as well as significant at 10 % of significance which indicated a positive influence towards level of satisfaction being a member. The results and findings of the study would be usful for that selected FPO for future strategic planning as well as would be help for other FPOs planning and management in general.

A system dynamics model for improving value chains in sorghum-dairy production systems

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Doubling the farmer's income is a hot debate among policy makers across India. To enhance the farm income, the scarce resources are to be integrated. This paper is mainly focused on the value chain development of sorghum-dairy production system (crop-livestock interaction) that provides intervention to enhance the farm income. Sorghum is extensively cultivated in hot and arid regions which is used for human consumption and as feed for animals. It is largely used in the dairy industry as it serves as a good substitute for high priced concentrates and other feeds. This paper provides a methodology for value chain development in complex interconnected sorghum-dairy production system by employing System Dynamics (SD). It quantifies multidimensional relationships between various value chain actors that profitably upgrade and commercialize the end produce. This methodological framework will ensure enhancing the farm income by producing the appropriate amount of produce in the supply-side.

Agritech start-ups in agricultural value chain in India

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Agritech startups in India are dominating the agri sphere with innovations in their business model using technology thereby increasing the efficiency and profitability in the agricultural operation. The study has tried to review the status of agritech startups using data from Startup India website and the respective websites of startups. It was also strived to find out the presence of startups in different stages of agricultural value chain. It was found that agritech startups account for 55% of the total agri startups in India. Only 11% of the total agritech startups have so far reached the scaling stage. The average age of agritech startups which are in the scaling stage is found to be 4 years. These startups are trying to solve specific problems of agricultural value chain with close to a quarter into technology based devices (IoT, sensor, artificial intelligence based) which improves the efficiency of agricultural production and operation. The next big category is e-commerce and marketplace for agricultural produce in the agricultural value chain. Presence of startups can be seen beyond the metro cities and innovative startups evolving from smaller cities too. Karnataka is leading the race in terms of total number of agritech startups which is also having maximum number of startups altogether. The presence of startups in dairy, aquaculture and poultry sector is very minimal, majority being present in the crop and horticulture sector.

Whether a revamped value chain is inevitable? The case of producer organizations involved in the production and marketing of 'neera' in the coconut sector

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Neera - the coconut inflorescence sap has been promoted as a potential value-added non-alcoholic beverage with abundant health benefits. The concerted effort of the stakeholder agencies could liberate the product from the policy regulations on its production under the excise act (known as 'Abkari act' in Kerala). Subsequently, the coconut producer federations (CPFs) in the state were granted licenses for 'neera' production and marketing. Notwithstanding the brighter projections on the sector, the majority of the CPFs discontinued the 'neera' enterprise, which they have initiated with greater enthusiasm. The present study is a modest attempt to trace the reasons for setbacks experienced in the 'neera' sector and also to provide a refined framework for revamping the sector. The details of licenses granted to the CPFs were sourced from the department of excise, Kerala. The size of the respondents was 177 (85 CPFs who are still active and 82 CPFs who had discontinued). It was observed that the 'neera' value chain is in the evolving stage and the withdrawal of the institutional support of coconut development board (CDB) had detrimentally affected the confidence of the CPFs ventured into it. The dearth of technical competence and lack of marketing skills were very much evident in the sector. The availability of 'neera' technicians

(tappers) and the high wage rates have evoked concerns on the profitability as well as the assurance of continuous supply of the product. The study categorically highlights the need for a restructured value chain of 'neera' with specific roles assigned to the stakeholders through the creation of functional linkages.

Youth – future of Indian agriculture: Are they really willing? – Evidence from Tamil Nadu

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The study attempted to analyze the factors determining willingness of students towards making agriculture as a career. Further, an effort was made to study the constraints in establishing their own farm immediately after graduation. About 397 agricultural students doing UG, PG, and Ph.D. degrees in Tamil Nadu were randomly surveyed during September, 2020. The results revealed that, about 25% of the students joined the course because of better job opportunities, and 19% to learn about farming. Nearly 48% of the students wish to be in a public sector job and only 11% chose to make agriculture as their career. Having own farm land, place of residence, parent's primary occupation, age, gender, types of crop grown, and mother's occupation had significant positive effect on students' willingness to become farmers, whereas, degree enrolled, and total farm land had negatively affected the students' willingness. Lack of remunerative price, unavailable credit at a low interest, poor social recognition was the major constraints for not involving in agriculture at an early age. Consequently, more than half of the respondents planned to do farming after 10 years of their graduation. Public policies could make efforts to reduce this period if agricultural graduates are to be among young people who engage in farming.

Precision dairy farming technologies: The future of dairy farms in India

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Precision dairy farming is one of the technology oriented production practices that is seen as the future of the dairy farming. Precision dairy farming involves technology enabled farming practices which are supposed to play a great role in the future. Particularly in the pandemic situations like COVID-19, it has become imperative to go for application of technologies in all facets of human endeavour including dairy farming. Precision dairy

farming involves the use of technologies to measure physiological, behavioural, and production indicators on individual animals. Precision dairy farming technologies help dairy farmers refine their management practices to ascertain farm efficiency. Precision dairy farming assures improvement of animal well-being with respect to conventional farming methods. The precision dairy farming is being effectively adopted worldwide with the objectives to (a) maximize animal per-formance, (b) early detection of diseases in individual animal, (c) management of herd-health and production problems and (d) lessen the use of medication through preventive health measures. Maximization of potential of individual animal, early detection of disease and minimization of the use of medication lead to better farm efficiency and profit realization. One of the advantages of precision dairy farming is that while dealing with the animals, there exist several practical and ethical concerns, however precision dairy farming assures improvement of animal well-being with respect to conventional farming methods. There are a number of precision farming technologies, which can be used to monitor, manage and control various parameters including pertaining to animal health, feeding and management to enhance productivity, efficiency and income by taking appropriate decisions in time.

Impact of NAIP on a value chain on enhanced productivity and profitability of Pashmina fibre

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Socio-economic status of the best Pashmina farmers in the area the beneficiaries were provided with a pashmina goat unit comprising of 9 does and 1 buck in year 2009 at the cost of 10% of original value. Interventions in the form of shelter, feeding and health management were provided free of cost. The units performed exceedingly well especially in Drass and Panikhar areas of Kargil. Success stories one from Panikhar and other from Drass (Kargil district) has been compiled.

Linking smallholder farmer collectives to market: A case study of MAHA-FPC

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Access to improved market and modern developments in science and technology are critical drivers of income and productivity in agriculture. There is an urgent need to boost direct investment in agriculture, intensify market access to farmers, improve food processing and value addition activities in rural areas. Lack of suitable synergy

between diverse stakeholders viz. farmers, input and technology providers, public policy implementers etc. has impacted forward and backward linkage benefits in agriculture and has restricted smallholder farmers' participation in the access to markets and technology. Collective action as an institutional arrangement is often advocated to reduce the twin prime challenges of agriculture – efficient price discovery through market participation and rising cost of technology usage for productivity growth. The present paper, is focusing on Farmer producers Companies (FPCs) as collective action institutions and tries to ascertain whether these institutions would be able to suitably bring in synergy amongst various stakeholders of Indian agriculture to enhance income and productivity, strengthen the supply chain and ensure value addition in agriculture. In India, more than 7,000 FPCs have been promoted by various agencies. However, very few are working as per the role intended. To address issues and challenges of FPCs, the Government of India introduced the concept of "State Level Producers Company (SLPC)" to cater to the marketing needs of FPCs of the State. This study follows the case study research design to examine the evolution, governance, and business operating system of one such SLPC – Maharashtra State Farmer Producers Company Ltd. (MAHA-FPC). It was observed that the MAHA-FPC has created an enabling environment for farmers, in general, and specifically, established better coordination among FPOs formed in the State; involved in the policy dialogue with the State and Central agencies; and facilitated in strengthening the backward and forward linkages of member FPOs. The lessons learnt would be useful for other such SLPCs to establish, promote agribusiness activities and inculcate entrepreneurial culture among farmer producers.

Comparative economic analysis of tapioca production through FPO's member-farmers vs FPO's non-member farmers in Karur district of Tamil Nadu

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The present study entitled, 'Comparative economic analysis of tapioca production through FPO's member farmers versus non-member farmers in Karur district of Tamil Nadu. The average size of holding of tapioca member-farmers was 3.005 hectares and average cropping intensity was 232.10%. The average size of holding of tapioca non-member farmers was 2.95 hectares and average cropping intensity was 227.80%. Educational status of the member farmers was significantly higher than the non-member farmers. Average cost of cultivation of tapioca was Rs 49323.14 per hectare for non-member farmers. The per hectare cost of cultivation of tapioca for member farmers was Rs 46708.58 per hectare. Estimated gross return of tapioca of member farmer was 105000 Rs/ha and obtained net return was 58291.42 Rs/ha. Estimated gross return of tapioca non- member farmers was 90432.07 Rs/ha and obtained net return was Rs/ha 41108.93. The B : C ratio of member farmers and non-member farmers was 1.2 and 1.04, respectively. The value of coefficient of multiple determination for tapioca member farmers was 0.69.. The value of coefficient of multiple determinations for tapioca non-member farmers was 0.65. At overall level the member farmers and non-member farmers ratio of MVP/PX is greater than unity in case of nitrogen and irrigation charges, indicated the underutilization of these resource. The ratio of MVP/PX is less than unity in case of plant protection, labor days, manures and phosphorus which showed excess utilization of those resources. Use of those resources should be curtailed down to maximize the profit.

Case study of KisanMitra Group, Latur, Maharashtra, India

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Warehouse receipt financing (WRF) can address challenges like access to credit for farmers, inefficiency in agricultural marketing, post-harvest losses and exclusion of farmers from mainstream supply chain. However, studies indicate that farmers are excluded from WRF across developing countries. Their exclusion is due to some constraints in existing WRF mechanism. These constraints are high transaction cost and perceived risk of losing existing buyers. A case study from Latur, Maharashtra is presented and analysed to look into how these challenges are addressed in its farmer friendly WRF mechanism. Findings extend WRF literature with a “one stop solution” WRF mechanism for farmers.

Smallholder farmers and agrarian distress in the dryland areas of Andhra Pradesh

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There is phenomenal increase in the number of smallholder farmers in India as well as in Andhra Pradesh in particular. From this context, it is imperative to study issues and concerns of the smallholder farmers in dry lands regions. The Rayalaseema region is located in Andhra Pradesh well-known for dryland crops and droughts. This dryland region is often witnessing irregularities and shortfall of rainfall which impacting the farmers by adversely damaging the agriculture. Cropping patterns are mostly dryland crops like, cotton, groundnut, jowar, ragi, pulses etc. The region is frequently affected with droughts causing farmers to face distressing situations. Crops grown in this region is highly sensitive to rainfall, irregularities of rainfall often curse the smallholder farmers and make them to fall in the trap of indebtedness, seasonal migration. In this context this paper analyses the combination of smallholder farmers and agrarian distress in dry land areas of Andhra Pradesh. In more details, paper presents the challenges faced by smallholder farmers in dry land cropping and vulnerability in terms their livelihood aspects. Paper is analyzed by doing the primary study in a village Nagasamudram where large number smallholder farmers living in Ananthapuram district.

Direct benefit transfer scheme for agriculture and its implications on smallholder farmers in West Bengal

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Over the years, increasing expenditures on agriculture but declining profitability was posing a serious challenge to the farmers in India to continue their farming business gainfully. The scenario was even more stressing in the state like West Bengal, where over 95% of farmers were belonging to small and marginal categories, operating less than a hectare of land. They have limited investment capacity and weak financial linkages with the institutional agencies, cannot buy the required agricultural inputs in time and thereby failed to change their cropping pattern towards high value crops. Declining profitability of agricultural production systems forced many of the farmers to look for non-farm livelihoods options, leaving aside agriculture as primary occupation. Realizing the problems, central government (*PM-Kisan*) as well as few other state governments in India launched direct benefit transfers (DBT) of cash schemes for farmers. The present study was conducted to know the implications of one of such initiatives, *Krishak Bandhu Scheme* implemented in West Bengal, on farmers' income. It was found that 58% of the farmers in study area were benefited under the scheme and received at least one or more installment from the scheme. On an average, the beneficiary farmers received Rs1757 per installment during January 2019 to April 2020. The assistance amount substantiated 9-16% of input costs incurred by smallholder farmers for growing different crops. Among beneficiaries about two-third utilized the cash mainly for agricultural activities such as buying seeds, payment to labor, buying fertilizer and pesticide etc. Farmers expected that the amount of financial assistance needed to be increased and disbursement might be given in time so that they can use it properly. One way of increasing the assistance could be, state's participation in the centrally sponsored scheme, *PM-Kisan* and disbursing the money through online transfer of cash directly credited to the beneficiaries' bank accounts instead of issuing the cheques. Cash benefits helped farmers to continue their agricultural operation even during the pandemic and lockdown situation due to COVID19 by reducing the input cost burden and the government should continue such scheme through inclusion of the excluded.

Quantum of input subsidies availed by farmers for wheat and paddy crops in Punjab: An economic analysis

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Input subsidies encourage farmers to use the resources judiciously for getting higher crop yields. Keeping in view the importance of subsidies in agricultural sector, the present study was undertaken to estimate the quantum of input subsidies availed by Punjab farmers especially those growing paddy and wheat. The data were collected

from a representative sample of 180 farmers from all farm categories encompassing one district each selected randomly from three agro-climatic regions of Punjab. The results revealed that the quantum of direct subsidy was mainly availed by medium and large farm farmers. Crop-wise subsidy pattern showed that paddy farmers availed Rs. 8486 per hectare while for wheat farmers it was Rs. 5763 per hectare. Withdrawal of subsidies may lead to a decline of 13% and 11% in the net returns from paddy and wheat, respectively. Fertilizer, power and diesel subsidies availed by large and medium farmers were comparatively higher. Major policy option was to lay emphasis on rationalization of subsidies in favour of marginal and small farmers with partial withdrawal and giving subsidies with a rider to medium and large category farmers in order to lower economic disparity in agricultural sector.

Dairying is an effective instrument for livelihood security: A study in rural-urban interface of Bengaluru

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This study was carried out to understand the rural-urban interface of dairying surrounding Bengaluru metropolitan city. Dairying has potential to generate additional income and employment for smallholders. Using data on 240 dairy farmers and 120 non-dairy farmers drawn from different layers of South and North transects the results revealed that livelihood index value was higher among dairy sample households, and among dairy farmers, a higher livelihood security index was observed in transition layers than rural and urban layers. Further the distribution of income in the case of dairy sample households was found equal in transition layer of north transect and urban layer of south transect. Dairying reduces income inequality and helps reduce the poverty.

Gender inequality in wage employment in rural Odisha: Some micro-evidence

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The advancement in agriculture brought about considerable changes in the availability of work, nature and type of work and earnings of male and female agricultural labourers. This paper applies t-test to find out the degree of gender inequality in wages and employment in one irrigated and another contiguous non-irrigated village in tribal-dominated Kalahandi district of Odisha. The results indicate that while availability of irrigation reduces the gender gap in employment; mechanisation certainly reduces the employment potential of women labourers. Though women are more productive than men in jobs which have been traditionally allotted to them such as

transplanting and weeding, receive significantly lower wages than their male counterparts for such work. However, the emergence of contract labour engagement in harvesting has enabled women labourers to earn wages at par with their men counterparts.

Dairy farming as a catalyst to improve livelihood of rural farm households in Gujarat

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With the Prime Minister's call to double farmers' income by 2022, a fair share of the onus falls on dairy sector. In 2012-13, around 81% rural households in Gujarat were engaged in livestock enterprise. This paper examines the contribution of dairy alongside that of cultivation to farmers' real income in Gujarat in 2003 and 2013. Real growth in expenses in dairy production is also ascertained for the same time points. Real income from dairy in Gujarat has more than doubled during the period. The distribution of income is found to be highly skewed across land classes, social groups and NSS state-regions in the state. Both real dairy expenses and receipts per liter increased by 3.5% and 3.3% respectively during the period. Dairy farming can be the vehicle to enhance farmers' income with targeted approach encompassing research for technological breakthroughs, infrastructure development, dairy development institutions and human resources crucial for growth in any sector.

Effect of COVID-19 induced lockdown on the livelihood of the farmers in Karnataka

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Karnataka's agrarian economy was on the receiving side when the COVID-19 induced lockdown was suddenly imposed. Agricultural supply chain was disturbed which directly impacted the farmers' livelihood. The monthly consumption expenditure pattern of the sample farmers was studied and it was found that food expenditure exceeded non-food expenditure. Amongst food expenditure they spent more on cereals and fruits and vegetables and in case of non-food expenditure transport and healthcare ruled the roost. Farmers in the study area had to forego a significant proportion of their income due to lockdown related obstacles like labor shortage, unavailability of packaging materials, insufficient storage facilities and high transportation costs. On a positive note, farmers received financial assistance through PM Kisan and MNREGA and some farmers also indulged in new income generating activities during the lockdown.

Is soil test based plant micro-nutrient application is profitable in pulse production? A micro-evaluation study of Bhoochetana Scheme

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In this study, the cost and returns, resource use efficiency and functional analysis of red-gram production among the beneficiaries and non-beneficiaries of Bhoochetana scheme have been reported. The study has been conducted in the Kalaburagi District of Karnataka State which economically backward, majorly comes under dry-land and red-gram is predominant crop. The study found that cost of cultivation of red-gram among beneficiaries was marginally higher than non- beneficiaries. But, beneficiaries harvested additional red-gram so their returns were also higher. Resource use efficiency was also higher among the beneficiaries and positive significant effect of the scheme on the production of red-gram is reported. Schemes, like this are highly beneficial for the dry-land farmers when they are implemented and monitored efficiently.

The extent of market dependence and expenditure pattern of casual labor in Udaipur district of Rajasthan

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Casual labor households live in the vicious circle of inefficiency – low wage rates – low consumption - inefficiency. For this study, casual labor has been divided into two categories viz., category I and category II, which are working in rural and urban areas, respectively. The comparison between both the category of casual labor showed that PDS played an important role in food security of labor households by way of providing food grains at cheaper prices and contributed in the consumption of cereals, pulses, edible oils and sugar. The consumption of food groups was higher in urban casual labor except cereals and vegetables. Rural casual found to produce higher farm produce for consumption compares to urban casual labor. Electricity expenses were the major contributor to the consumption of the non-food item followed by education, intoxicants (Pan, tobacco and alcohol), clothing and footwear and travel expenses in rural casual labor households. In urban casual labor households, major expenses were on electricity, travel, education, intoxicants and clothing and footwear.

A study on growth performance of crop insurance schemes in India

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Dependence of agriculture on monsoon makes it a risky venture and is the root cause of agricultural crisis and farmers' suicides in the country. Around 42.4 thousand farmers and daily wagers committed suicide in 2019 registering an increase of nearly 6% compared to previous year. Different approaches have been evolved; wherein adoption of a robust crop insurance system is one such mechanism that cushions the shock of crop loss by assuring protection to farmers against natural hazards which are beyond their control. The present study attempts to analyze the growth performance and variability of two most important crop insurance schemes of India; NAIS (1999-2000 to 2015-16) and WBCIS (2007-08 to 2015-16). The results revealed that positive growth rates have been observed for all the aspects under both the schemes during the period of their implementation. For NAIS, maximum growth rate as well as instability index is reported as 26.11% 79.62% for claims paid to the farmers. The compound annual growth rates computed for number of farmers insured, area insured, sum insured, gross premium, farmers' premium, gross premium collected and number of farmers benefitted were reported as 10.43, 8.98, 21.49, 23.25, 23.1 and 13.93%, respectively. On the other hand, for WBCIS, the highest CAGR of 65.07 per cent was found for the number of farmers benefitted from the scheme whereas the highest instability index has been reported as 40.80 per cent in case of sum insured. The compound growth rates for number of farmers insured, area insured, sum insured, farmers' premium, gross premium collected and claims paid have been calculated as 50.48, 44.19, 41.82, 58.67, 47.85 and 57.32 %, respectively.

Exploring mitigation strategies for elephant induced damages in India's coffee plantations

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Coffee plantations are agroforestry systems that witness frequent occurrences of human elephant negative impact due to their shared landscape and proximity to forest reserves. Crop losses from these negative impacts are a major threat to the livelihood of coffee planters and overtime various strategies have been adopted to prevent/mitigate losses. However, despite efforts, negative interactions remain pervasive, and in many plantations the damage has intensified as a majority of the strategies are site-specific, short-term and often transfer negative impact risk from one place to another. This paper reviews various mitigation strategies and presents stakeholders' perspectives in Indian coffee plantations for exploring alternative or complementary approaches through evaluations to minimize planter's losses and advance towards coexistence.

Agricultural labor migration in Raichur and Yadgir districts of Karnataka: Nature, trend and determinants

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The present paper intends to examine the nature, trend and determinants of agricultural labor migration in Raichur and Yadgir districts of Karnataka. The results revealed that the majority of population were inter district migrants with the highest decadal growth rate of 68.53%. And it has also used latest census 2011data and made compared with previous census report of 2001, revealed that highest per cent of migration was in rural as compared to urban area. The most of the labourers in irrigated situation migrated near village and within the district but in rainfed situation, labor migration to other districts was relatively high. In both the situation majority of labourers migrated permentally and the frequency was highest (62.5%) in rainfed situation. The elasticity coefficients for wage rate, land holding, family size and indebtedness were significantly influencing the migration in the study area.

How do migrated farm labours respond to livelihood security? Evidence from North Karnataka region

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Response of the migrated labours to livelihood security during covid-19 pandemic in North Karnataka is studied. This study ascertained the alternative livelihood options of migrant labours those went back to their hometowns to survive during pandemic period. The purpose of this paper is to identify the nature of livelihood security using logistic regression. The results of logistic regression found that the factors influencing upon livelihood security consisted of family size, household income, and income from non-agriculture, dependency ratio, migrating reason, and average age of migrants. This study not only highlights the socio-economic conditions of the migrants but also exhibits the factors affecting the livelihood security of migrant workers.

Public expenditure, subsidy and growth in agriculture: A case study of Rajasthan

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The study examined the trade-off between subsidy and public expenditure in agriculture, and compares the effectiveness of agriculture subsidy with that of agriculture expenditure on agriculture growth in Rajasthan. The study used time series data from 2005-06 to 2018-19. Our findings reveal that agriculture subsidy and public expenditure in agriculture do not have any trade-off. Moreover, public expenditure in agriculture is more effective than subsidies in accelerating agriculture growth. The subsidy did not have significant influence, but agriculture investment have positive influence on agriculture GSDP, which implies that public expenditure is more effective than subsidies in Indian agriculture. Therefore, it is suggested to the government to gradually convert subsidies into agriculture investment for sustainable and efficient growth of agriculture.

Trends in land utilization pattern and market sentiments *vis- a- vis* doubling farmers' income

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The study attempts to analyze land use dynamics in Karnataka based on secondary data from 2008-09 to 2016-17. The decadal shift in cropping pattern shows positive acreage allocation for maize, nutria-cereals, pulses and commercial crops like sugarcane, cotton, oilseeds, tomato and onion. The survey of 200 farmers from five districts revealed that farmers' eke out living through income from diversified sources like dairy, remittance by family members and labor wages. The average annual household income of Rs 1,95,862. For more than 50% of respondents, doubling farmers' income is an indomitable task under the prevailing production and market conditions.

Economic impacts and inequality mitigation of wicker handicraft entrepreneurship in rural Kashmir, India

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This paper has investigated the economic impacts, income inequality mitigation and determinants of wicker handicraft entrepreneurship in Pulwama district of Jammu & Kashmir. Results show that collection of withies from *Parrotia jacquemontiana*, *Cotoneaster baciliaris*, *Indigofera pulchella* and *Salix* spp. was 61.71 t/year for manufacture of 43514 wicker handicrafts that generated an income of Rs 5953470/year. Wicker handicraft income contributes 66.97%, to the household income, followed by farm (23.46%) and non-farm (9.58%) incomes. Gini coefficient was 0.37 when wicker handicraft income was considered, and 0.53 when it was ignored. This indicates that the wicker handicraft income has strong equalizing income distribution. Regression analysis showed that all explanatory variables jointly accounted 81.50% of the variation in the wicker handicraft income. Education, family composition, housing status, subsequent occupation and gross annual income were key factors influencing wicker handicraft income. To achieve the socioeconomic development and livelihood diversification the policy must be directed towards development of rural industries such as wicker handicraft.

Impact of COVID-19 on the fundamentals of Indian cotton sector

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Movement restrictions around the world to contain COVID-19 disrupted the commodity supply chains. As Indian cotton sector is a major income and employment provider for the farming community, an attempt has been made to analyze the impact of COVID-19. Simulations for increase in carry over stock and reduction in domestic consumption and exports revealed that reducing cotton production and supply would retain the market equilibrium and increase the domestic price to the advantage of the farmers. Appropriate planning for area under cotton cultivation and the procurement mechanism would stabilise the Indian cotton economy.

Assessment of impact of COVID-19 on farmers' outlook and perception in Telangana state

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This paper discusses farmers' outlook and perceptions in Telangana during COVID-19 pandemic induced lockdown. A sample of 200 farmers were selected randomly. Majority of the farmers expressed that impact of lockdown was moderate on agricultural operations in standing crop, and severe on availability of labor supply and availability of transport facilities. Nearly 80% of the respondents were happy with the grain procurement scheme of the state government and majority of the farmers (33.5%) approached agricultural extension staff during the lockdown. 47% of the farmers have taken loans from public sector banks. Almost 53% were gearing up for next *kharif* season and 46% of farmers were having an apprehension of cost of production may increase because of COVID-19 crisis. About 86% farmers felt safe by being in villages. ANOVA test indicates that there is a significance difference of opinion about COVID-19 impact among farmers based on type of crop, age group and land holding size.

Diversification on small and marginal farms in Himachal Pradesh: Challenges and opportunities

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The total number of small and marginal farms in Himachal Pradesh increased significantly whereas it decreased for other categories of holdings. Majority of farmers in the rural areas of Himachal Pradesh cultivate mainly low value subsistence crops. In the absence of adequate farm and non-farm employment opportunities, they are forced to live below poverty line. There is limited scope of increasing production through expansion of cultivable land. Hence, there is a need for diversification of farms within and outside agriculture. The principal objective of the study is to discuss the scope for agricultural diversification in Himachal Pradesh. An attempt has also been made to examine the opportunities and challenges of agricultural diversification in the state. Secondary data has been used to find out the ultimate goal. The study revealed that agricultural diversification is a major step towards the improvement of the rural economy and it is the best solution for reducing the production uncertainty. The farmers need to be taught about the new cultivation practices and mixed farming for this purpose. Arrangements should be made to provide them high yielding seeds, new technologies and subsidized fertilizers.

Impact of Mahatma Gandhi National Rural Employment Guarantee scheme on consumption expenditure pattern of non-food items of rural women labor in Punjab and Karnataka

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Using primary data on the annual spending pattern of rural women labor under MGNREGS, on non-food items revealed that after the implementation of MGNREGS, total annual non-food expenditure were Rs.12383 per labor. The percent expenditure found that health Rs.1948 (16 per cent), education of children Rs. 1464 (12%), clothing Rs. 1534 (12%), consumer durables Rs. 980 (8%), religious and family ceremonies Rs.750 (6%), cooking Rs.1106 (9%). Similarly, in Karnataka, annual non-food expenditure were Rs. 18,755 per labor. Repayment of debts were Rs.2580 (14%), cooking Rs.3365 (18%), transportation Rs.2274 (12%), consumer durables Rs.2028 (11%), and education of children Rs.2002 (10%). Therefore, MGNREGA helped in improving the income and consumption- expenditure pattern among rural women labours.

Crop diversification and area shifts of paddy in coastal region of Andhra Pradesh

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An attempt is made in the present study to analyze growth rates and instability of annual rainfall and sources of irrigation. Simpson diversification indices were calculated to know the extent of crop diversification and Markov chain analysis was employed to know area shifts of paddy under irrigated and unirrigated conditions in the coastal region of Andhra Pradesh. The mean annual rainfall was below the normal annual rainfall. The area under irrigation provided through project canal showed significant negative growth rates and tube well showed significant positive growth rate. The districts with lower SDI (Simpson Diversification Index) value have higher irrigation intensity value, which clearly indicated that under irrigated conditions crop concentration was very high. All districts showed considerable retention in previous year area share of paddy under irrigation. There is a need to motivate the farmers to diversify the cropping pattern through changes done in major rice-based cropping systems and adoption of water saving technologies.

Dynamics of cropping pattern of onion in Rayalaseema region of Andhra Pradesh

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An attempt is made in the present study to analyze growth rates and instability of annual rainfall and sources of irrigation, Simpson diversification indices calculated to know the extent of crop diversification and Markov chain analysis was employed to know the area shifts of onion under irrigation and unirrigation facility in Rayalaseema region of Andhra Pradesh. The analysis was carried out from 2001-02 to 2018-19 and the results revealed that the districts with highest area under irrigation facility showed more crop diversification when compared with other districts of Rayalaseema region. Chittoor district was reported with high crop diversification and Ananthapuramu with low crop diversification. The Chittoor district analysis revealed that retention of onion previous year area share was 37.44 % and remaining districts showed no retention of previous year area share under overall gross cropped area. The present study suggests that to accelerate the pace of diversification from cereals to vegetable crops and commercial crops in the Rayalaseema region of Andhra Pradesh, steps need to be taken to improve rural infrastructure such as irrigation and marketing facilities.

India's food system and food environment and its possible impact of COVID-19 on food security: Insights from selected locations in Telangana, India

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ICRISAT undertook a telephonic survey during July -August 2020 to understand the different perspectives of prevailing COVID-19 crisis in urban, peri-urban, rural and tribal areas of Telangana. About 40 households were randomly selected for this survey covering urban, peri-urban, rural and tribal locations of Telangana. These households were recruited as respondents for previous surveys by ICRISAT for different projects. The NNEDPro survey questionnaire was adapted and translated into local language for better understanding of the surveyor as well as the participant and probe questions were added for eliciting detailed information. Informed audio consent was undertaken through mobile phone and the personal individual interviews were conducted to elicit the data regarding the agriculture and food security situation during the COVID-19 crisis in their respective locations. The recorded data was transcribed by the enumerators and later translated into English language. Mixed responses evolved with regard to agriculture and losses incurred during COVID-19 crisis.

In case of urban and peri-urban locations, information on agriculture especially post-harvest losses due to lack of access to markets was projected and the source of information was mostly through secondary source of information through media such as television news, newspaper and radio. In case of tribal areas, millets and cereals were procured by government agricultural department at the farm gate thereby no losses were incurred by farmers who grew cereals and millets. The farmers who grew vegetables incurred losses due to lack of conveyance/ transport to the nearby markets during the complete lockdown. As the vegetables are perishable goods, and due to shortage of labor for harvesting the produce, they incurred huge postharvest losses.

Consumption of cereals and pulses distributed through Public Distribution System (PDS) has increased at the household level in peri-urban areas. Consumption of fresh fruits and vegetables and spices has also increased in both urban and peri urban locations. There was no change in the number of meals consumed and quantity of meals (rather quantity was reduced due to low physical activity and being confined to homes) while home cooking was the most preferred choice. Outside food and junk food was almost completely eliminated in the diets of the urban and peri-urban areas. In case of tribal areas, the adolescents and school age children lost their nutritious meals that were served either in their residential schools or midday meals in the government schools.

There also emerged some differences between complete lockdown that was in place in late March and early April 2020 and the lockdown with fewer restrictions during June-July 2020. Similarly, the effect of food security at the household and individual level emerged differently across locations as well as during different periods.

Food and nutritional security of farm households in Meghalaya: A food basket approach using temporal and spatial analysis

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The households were recommended to consume the right quantity of balanced foods, equivalent to approximately, 2400 Kcal per capita per day in the rural areas and 2100 Kcal in urban areas. However, in the last 20 years, there have been no significant changes in patterns of dietary intake in India and cereals remain the staple food providing most of the energy intake. The National Sample Survey reported that the calorie consumption at rural India and urban area was 2099 and 2058 Kcal per day per capita during 2011-12 which was concluded to be of improvement than the previous years. However, additional concern is that anthropometric indicators showing nutrition in India, for both adult and children, were among the worst in the world. The farm households of NER were found to be more food insecure in the country. In Meghalaya, the per capita per day intake of energy was the least among Indian states. The food availability in the state is mainly through three main sources for rice which was own farms, PDS and markets whereas for other food commodities it was mainly through on farm produced and markets. The maximum of the calorie intake among foods has been largely contributed by rice (71.94 %) which was the staple food in the state with an overall contribution of 1726.50 Kcal per person per day. The study concluded that the state has a gap or deficit in the calorie intake by 313.59 kcal per person per day with only 62.33% households being sufficient in the food intake.

Correlates of food security of farming households in the rural-urban interface of Bengaluru, India

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Agriculture, food and nutritional security are linked intrinsically. Agriculture is important in ensuring food security, not only as a source of food production but also a source of livelihood. Poverty alleviation implications of agriculture is well documented in the literature, which again has a direct implication on both food and nutritional security. Understanding the food and nutritional security of the farming households in this line can give us important insights, particularly in the context of urbanization, due to which both agriculture and lifestyle are changing. The study examines the food security of the farming households based on a detailed primary data of 1200 households. The food security was estimated based on Food Security Index. Factors influencing the food security was estimated based on multiple regression analysis revealed that land holding has positively associated with food security while family size has negative association with food security index.

Spatial fish consumption patterns across Andhra Pradesh

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The current paper endeavors to evaluate the spatial pattern of fish utilization and its attributes in Andhra Pradesh. The study was directed over the distinctive regions viz., urban coastal (Visakhapatnam), rural coastal (Vizianagaram) and non-coastal urban (Kurnool) and non-coastal rural (Anantapur) districts. A total of 1440 fish consumption households was secured for the study. The buyer profile uncovered that 88% respondents were of middle age group (20-50 years) with higher secondary education (29%). More than 60% devour fish consistently because of better accessibility, availability and affordability. The consumption traits indicated that seer fish was the most favored species followed by pomfrets and shrimps. The constraints in fish consumption as perceived by the buyer's incorporated absence of fresh and preferred fish, exorbitant price, wide vacillations in price, unpredictable supply and absence of cleanliness in buy sources filled in as restricting components in expanding fish consumption. Diverse statistical and econometric apparatuses, for example, conjoint analysis, preference assessment index and discriminant analysis were utilized for analyzing the information.

Animal menace in Western Himalayan foothills: Farmers' perceptions of origin, pattern and crop damage

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Agriculture provides livelihood for the majority of the rural households of hilly regions. The population of both wild as well as stray cattle in these regions is continuously increasing and has assumed the form of menace. As such, animal menace has emerged as one of the major threats for farming. The present study is based on the primary data collected from 60 farm households selected through three stage random sampling technique in Kangra district of Himachal Pradesh. The study examined various aspects of this problem such as animal species responsible, frequency of crop raiding, extent and degree of menace and crop damages, etc. The results revealed that cattle, monkey, wild boar, *sambhar* and *nilgai* are the major animal species associated with crop damages. Among these, the problem of cattle was reported to be of relatively recent origin (2-5 years) compared to wild animals' menace (5-10 years). During 2009-2015 period there has been a significant increase in animal population: it increased from 1.68 to 8.53 in case of stray cattle while it went up from 5.66 to 29.48 for wild animals with monkey as dominant species. The majority of the respondents were of the view that these animals raid the fields once in a week during day/night hours. As far as degree of menace was concerned, the problem of wild animals was more serious compared to the stray cattle, around 47 and 33 per cent of the respondents attributed the degree of menace as of medium and high degree, respectively. Further, among the wild animals the degree of monkey menace was the major concern round the year (summer, winter and rainy season). Stray cattle, *sambhar*, *nilgai* were found to damage the crops during all stages while monkey and wild boars damaged the crops during reproductive/maturity stage. In vegetative growth stage cattle caused highest loss to crops while during maturity stages of crop, monkey were responsible for highest extent of losses to crops.

Crop diversification: Determinants and its impact on income and employment of farm households in Nagapattinam district of Tamil Nadu

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Crop diversification is an effective climate smart intervention for agricultural development of coastal areas. The study analyzed the impact of crop diversification on farm households in Nagapattinam, a coastal district in Tamil Nadu based on survey data from 120 farmers in six villages each from high (HDZ) and low diversification zone (LDZ) in Thalainaiyuru block of Vedaraniyam taluk. Major crops were rice, mango and coconut in HDZ and rice and pulses in LDZ. Simpson Index was 0.56 in HDZ and it ranged from 0 – 0.13 in LDZ. Multinomial logit revealed that education, irrigation, access to credit and extension influenced crop diversification. Labour use was

high for bhendi (318 mandays/ha) and brinjal (297 mandays/ha) in HDZ; it was 54 mandays/ha and 20 mandays/ha respectively for rice and pulses in LDZ. Returns Per Rupee of Investment was high for brinjal (4.78) followed by bhendi (4.34), groundnut (2.37) and rice (1.68) in HDZ; and low for rice (1.39) and pulses (1.27) in LDZ.

Supply, demand and exportable surplus of rice: Present *vis-à-vis* thirty years ahead

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This study projects the future demand and supply of one of the most important food grains of Indian food security basket, i.e., rice for the year 2020, 2030, 2040 and 2050 based on historical data on area, production and yield (APY); NSSO data on per capita consumption of rice and population forecasts of the United Nations (UN) for India. Further, the study classifies different rice producing states based on productivity into high, medium and low yielding states which are vital for initiating policy actions for strengthening the rice production from the ecologically favourable but low yielding regions. State wise APY data for the year 2018-19 indicates the typical concentration of rice cultivation in the eastern and southern Indian states. Also, the eastern states, though accounts for the greater area and production but with the lowest yield, while higher productivity of north and south zones can be attributed to better irrigation facilities. During 1950-51 to 2018-19, rice production witnesses an average growth of 2.45 per cent per year. Projected estimates indicates that Indian rice production may attain about 160 million tonnes by the year 2030 to 259 million tonnes during 2050. Further, the supply- demand differences for future indicates that, India would retain surplus of about 62 million tonnes of rice by the year 2050 after meeting the consumption demand for about 1.65 billion future population. Further, on the policy issue on dipping rice area in the country, it was also assessed that had the rice area remains the same as in 2018-19, yield level need to be increased by about 1.83 t ha^{-1} and if rice area decreases by 15 per cent, incremental yield to fed the burgeoning population would be around 2.62 t ha^{-1} during the year 2050.

Transformation in agricultural landscape of Tapi: An assessment for okra commercialization

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The commercialization of okra in agricultural landscape of Tapi is essentially an outcome of the institutional interventions during the past four decades. These interventions have been found effective in transforming the regions agricultural sector from parochial paddy cultivation to commercial cultivation of okra. The major marketing-centric institutional interventions of the export promoting agencies have highlighted the relevance of

institutional innovations in the promotion of okra in the region. The study has shown the potential benefits of comprehensive institutional interventions persuaded by the export agencies in Tapi. A comparative analysis of marketing has revealed that marketing channel of okra via. exporting agency is the most efficient. The study has demonstrated the benefits of informal community participation with proper guidance and monitoring.

Consumption pattern, demand and supply of livestock feed and fodder in Gujarat

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This study examines consumption pattern, demand and supply of feed and fodder production in Gujarat. Field survey indicate data that the average feed and fodder consumption of milch animals was ranges between 14- 16 kg of green of fodder followed by 12-14 kg of dry fodder, 2-3 kg of concentrates and very few quantity of the supplements were fed to the adult animals. The state is deficit in concentrates around 84%, and in dry fodder around 28%. The green fodder availability is in excess by almost 30% than requirement. The gap between the requirement and availability of feed and fodder is increasing due to decreasing area under fodder cultivations and reduced availability of crop residues as fodder. Also there is continuous shrinking of common property resources leading to over grazing on the existing grass land. Therefore, there is a need to work out the strategies for sufficient good quality feed and fodder for efficient utilisation of genetic potential; of the various livestock species and for sustainable improvement in productivity. Besides, fodder community farming farms should be encouraged. Co-operative farming of fodder particularly on the barren land of the village can assure sufficient local availability of the fodder and thereby reduce the variable cost, create a positive impact on net income.

Pattern of crop diversification and its implications on undernutrition in India

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This paper explores the pattern and extent of food crop diversification and its implications on nutritional indicators in India, using district-level data for the most recent period. The study relied on data from Land use statistics and the National family health survey, 2015-16. We estimated the Simpson index (Sd) for food crop diversification and undernutrition index for nutritional status. The association of crop diversification and nutritional status was analysed employing bivariate copula function. Our findings show striking regional differences in the extent of food crop diversification and nutritional outcomes. The results of the copula function indicated a significant inverse relationship between crop diversification and undernutrition. These findings suggest a need to promote diversification among food crops by introducing crop neutral policies to bridge regional gaps in nutritional outcomes.

Levels, pattern and distribution of consumption expenditure of marginal and small farmers in rural Haryana

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The objective of the paper is to analyze levels, pattern and distribution of consumption expenditure of the marginal and small farmers in rural Haryana. The study concludes that about 60% of the total consumption expenditure is incurred on non-durable items by these two farming categories followed by durables, services and socio-religious ceremonies. The propensity to consume is more than one for both the farm-size categories which has an important implication that in the rural areas of Haryana these farm-size categories try to maintain a minimum level of consumption whether they can afford it or not. The present study is based on 554 marginal and small farm households to the year 2014-15.

Crop diversification towards high-value crops in Rajasthan

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The paper examines the state-level pattern of crop diversification during pre & post-liberalization period from 1980-91 to 2017-18 in Rajasthan. The overall annual growth rate in area was highest in case of condiments and spices (3.80 %) followed by fruits & vegetables (3.57 %) while lowest growth in food grains (0.01 %) and pulses (0.24 %). The production of fruits & vegetables has also shown highest positive growth rate (9.58 %). The Herfindahl Index has shown variation where it reduced to zero in 2000-01 showing complete diversification which changed in 2010-11 and remained the same in 2017-18. This means a variety of high-value crops were grown in Rajasthan.

Role of public intervention in conservation of paddy ecosystems in Kerala, India: An empirical evidence

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Cropping pattern of Kerala has witnessed a shift from paddy to cash crops as elicited from Markov chain analysis in the study. Low profitability of paddy farming in the state resulted in paddy ecosystems being converted on a large scale. The resultant twin issues of falling agricultural growth and ecological disturbance prompted Government of Kerala to enact the 'Kerala Conservation of Paddy Land and Wetland Act' in 2008. Structural break analysis revealed that the Act could significantly arrest reduction in paddy land area in Kerala. This reflects on the scope of public interventions in conserving important agroecosystems worldwide.

Socio-economic status of agricultural labor in Punjab

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The present study has been designed to investigate the socio-economic status of agricultural labor in Punjab. The primary data was collected from 270 agricultural labourers in three different agro-climatic zones of the state. Young agricultural labourers are more in demand for farm related activities. There was existence of child labor especially under permanent local labor or in transplanting of paddy. About 10% of the sampled labourers were under the age of 15 years. Significant number of aged agricultural laboures were also working on farms. Most of the agricultural labourers were school dropouts. Government schools were the only source of education for most of the respondents due to their weak financial situation. It was observed that few of the workers were living in Punjab and even holds the domicile status of state, but, there place of birth was not in Punjab. Study observed that there was a direct relation between following a certain religion and being an agricultural labourer. It was observed that 10% of the agricultural labourers in Punjab were either widower or window and it disturbed the social structure very badly.

Value chain finance to dairy sector - A case study of eastern Uttar Pradesh

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The study has analyzed the value chain finance of dairying in eastern Uttar Pradesh based on the data collected from 64 milk producers in 8 villages, 3 inputs suppliers, 8 milk collectors/assemblers, 4 milk transporters, 1 milk processor and 12 distributers for the year 2019-20. The study observed that there is vast network of financing institutions. However, there are also several informal mechanism of value chain financing. The study found that financing agencies have identified the set of activities associated with milk value chain and determine the structure of finance accordingly, in order to minimize costs, to maximize efficiency and to reduce risk. The study has also inferred that among all the actors involved in milk value chains, the processor, producer and distributer have added greater value addition, and they need to be strengthened through the value chain finance approach for the better growth of the dairy industry.

Efficacy of Holt-Winters forecast on seasonal time series crop insurance data with structural outliers

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The study analyses the components of time series data on crop insurance of the state of Tamil Nadu, India. The data was found to be seasonal and exponentially increasing. Multiplicative Holt-Winters Model was applied in order to do short range forecast. The model was run in Ms-Excel in order to understand the basics of times series forecasting. Minimum MSE value was the criteria used to find the better fitting smoothing values. The residual of the model was examined for the fit of the model. Residual mean value was close to zero. Residuals are tested for autocorrelation with Durbin-Watson test and Runs test. Histogram of residuals implies a normal distribution. Presence of outliers are detected using 3IQR method and the identified outliers are part of the structure of data and need not be removed. However, alternate models of Holt-Winters itself which are robust to work with outliers are reviewed.

Analysis of market efficiency for potato markets: A study of five major assembling markets in India

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The study was undertaken to analyse the market efficiency of potato prices from July, 2005 to June, 2020 in Agra, Hooghly, Firozpur, Pune and Delhi markets. After establishing that price series were stationary and integrated of the same order, co-integration test for the long run relationship among the price series was conducted which revealed that all the selected markets were well integrated. Speed of adjustment was found highest in Agra (30%) and Firozpur (14%). The causal relationship between the price series in potato markets was approached through Granger causality technique and Delhi market was found to be the price leader. The shock arising in Delhi market gets transmitted to all other markets with a higher response in the approaching months. To identify the price triggers in major influencing markets, variance decomposition technique was applied which revealed that forecast error variance in Delhi was well explained by variable itself both in short and long run.

Price behavior and market integration amongst the major potato markets of India

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Potato is one of the most important food crops in India. Variation in output of potato leads to wide fluctuation in its price exposing the growers to a high risk situation. To cope with this, information on potential markets and prices of potato in different months is necessary for the farmers. The present study was undertaken to analyze the price behavior of potato producing (Lucknow, Kolkata and Patna) and consuming (Mumbai, Ahmedabad, Delhi and Ludhiana) markets using monthly wholesale price data from January 2012 to December 2019. Correlation analysis, Johansen co-integration test, Vector Error Correction Model and Granger causality were used for the analysis. Instability in the price series was measured by Cuddy Della-Valle index. The maximum instability in potato prices was different for different markets ranging from September to February and seasonality index showed that farmer received more than average price between June to December. This information on price behavior could be useful to farmers to make their marketing decisions. Johansen co-integration test revealed that all the selected markets were well integrated in the long run. The speed of adjustment was highest in Patna market (80%) followed by Mumbai market (13%). Majority of the states have shown unidirectional price transmission and Patna is the only state which has indicated bidirectional flow of potato prices with Kolkata market. Delhi market was found to be the key market which influenced the price of all other markets by Granger Causality test.

Rural agriculture and market access during Covid 19 pandemic: The case of paddy farmers in Kerala, India

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The market access to paddy farmers in Kerala state and attempt to quantify the losses to them during the lock down period. The results show that 89% of the paddy farmers accessed public procurement system. Marketed surplus was greater than marketable surplus for more than fifty percent of farmer. On an average, total economic loss due to lockdown for paddy farmer amounted to Rs.3691.72/Ha. The market access available to the paddy farmers in Kerala during lockdown period in the form of public procurement system turned out to be the most effective marketing channel.

Study of investment on major crops grown by marginal and small tribal farmers of Dhar district, Madhya Pradesh, India

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Madhya Pradesh has largest tribal population in India. Dindori, Mandla, Betul,Chhindwara, Dhar and Jhabua are major tribal districts. Dhar is in close proximity of Indore, an educational hub, an industrial and financial and civilized city of Madhya Pradesh. The conditions of tribals in this district are different than in other tribal districts. A list of total blocks of Dhar district was prepared and on the basis of the total tribal population , first five blocks namely, Badnawar, Dhar, Manawar, Dharampuri and Nalchha have been selected . A list of villages of tribal farmers of each selected blocks were prepared and 5 villages from each block have been selected purposely of the basis of maximum tribal farmers in the village. Accordingly, 25 villages falling in 5 selected blocks were the total sampled area of study. After the selection of villages, separate list of marginal and small farmers who were cultivating soybean, cotton, wheat and gram were prepared with the help of Deputy Director of Agriculture Dhar . Among these lists 5 marginal farmers (0.1 to 1.00 hectare.) and 5 small farmers (1.01 to 2.00 hectare) from each village have been selected randomly. Thus, 125 marginal farmers and 125 small farmers were selected. Total kahrif area comprises 504024hec.; as compared to rabi crops(134716hec.) covering wheat, gram and some other rabi crops. Soybean accounts about 49 % area of kharif crops, followed by cotton 22%. It found in the study that area under soybean was found to be 0.79 hectare per farm followed by cotton 0.82 hectare.

Institutional innovations in marketing of fruits: A case of Farmer Producers Organization (FPO) of fig in Raichur district, Karnataka

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The importance of dry land fruit crops is well known due to their high nutritive value, low cost of production and little care required for their management. However, the small size of marketable surplus of the farmers due to tiny landholdings has led to marketing problems even for fig growers. The size of operational holdings in India is continuously declining with every successive generation. The situation has raised serious question on the survivability of these small holders. In this context, aggregation of the farmers, especially small and marginal farmers, into producer organizations has emerged as one of the most effective means in the recent past to address many challenges of agriculture. Hence, the present paper is an attempt to understand the activities of such of the organizations which have been emerged for the said purpose with the case study approach. The *ParisarPremi* FPO established on 1st July 2017 as of now has 1130 members composed of mainly small farmers (50%) followed by medium farmers (30%) and large farmers (20%). The FPO has provided several services to its members like technical guidance, input supply, marketing services, etc. It is worth to mention that FPO would able to generate assets with the support of Government schemes within a short span of three years. The FPO members would able to save in the maintenance cost of fig to the extent of 7.73 percent over non-members due to reduction in the input cost. The improved production technology and better technical knowhow of the member farmers helped in realization of better yield (27.66%) over non-members. Above all the member farmers have sold the fig through different methods like open market, supermarket chain and usage of WhatsApp group for sale of fruits. The FPO member farmers have realized highest net price for the fig sold through supermarket chain (Rs. 72/kg). The organized efforts of FPO lead to supply the produce to higher value markets, which fetched higher net price than any other methods used for fig in the study area. This helped in realizing higher returns for the member over non-member farmers. Thus, promotion of FPO would bring in better input and output marketing and thereby brings the economic sustainability among farmers.

Impact of COVID-19 induced lockdown on wheat prices: Empirical evidence from interrupted time series analysis

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COVID-19 incidence disrupted the food markets in India. The present study, adopting the interrupted time series analysis (ITSA), captures the impact of pandemic induced lockdown on wholesale and retail wheat prices. Prices increased post-lockdown, however, there was no evidence of structural break as well as persisting volatility

implying that the lockdown had no lasting impact on wheat prices. Retail prices witnessed an immediate increase post-lockdown across the country but significant only in west and north-east zones, and showed a decline in north and east zone. On the contrary, wholesale prices witnessed an immediate and significant increase in west and north-east zones; with a significant decrease in south zone. A negative post intervention trend in ITSA confirmed the result as a majority of the market zones reverted back to pre-lockdown levels which shall be attributed to the wheat arrivals post bumper harvest. Despite the relaxation allowed for agricultural related activities during the lockdown, price change in wheat has been observed across regions but reverted back owing to the system resilience. The ûndings affirm that market disruption is the main driver behind the observed price changes.

Invisible monopsony in Indian sugar sector

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Sugarcane market in India is almost turning monopsonic given the trend in declining jaggery processing units coupled with policies like cane reservation area and minimum distance criterion. With the exploratory research approach, this article tries to identify the monopsonic characteristics exhibited by the sugarcane market, the reasons behind it and its impact on sugarcane farmers and millers. Single buyer, restriction on entry of firms, geographic immobility of the seller and buyer being the price maker, are some of the monopsonic characteristics exhibited. The reasons behind it could be deteriorating jaggery sector, lobbying capacities of sugar millers and inclined State support towards sugar mills. This kind of market structure has several negative impacts on its stakeholders like a limited opportunity for the seller to select their buyer and *vice versa*, low welfare as compared to perfect competition, farmers lose their control over their micro-level decisions.

Economics and marketing of broiler and layer farming in Ajmer district of Rajasthan

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The present investigation was carried out in Ajmer district of Rajasthan by purposively selecting ten poultry farms. The primary data were collected through structured questionnaire as well as self- observations. The study calculated per bird total cost, gross returns and net returns as Rs 122.67, 182.14 and 53.21 for small scale broiler farms, respectively. For the large size broiler farms the per bird total cost, gross returns and net returns were Rs 114.12, 176.12 and 62.00, respectively. The results also found that for layer production the per bird total cost,

gross returns and net returns were respectively at Rs 489.06, 777.33 and 288.27 for small scale farms and Rs 448.21, 760 and 311.79 for large scale farms. There were five major marketing channels have been found for marketing of both broiler and layer farming in Ajmer district of Rajasthan.

Assessment of co-movement of kinnow prices among the domestic markets in Punjab

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The study attempts to analyze the weekly co-movement of kinnow prices among the domestic markets in Punjab from 2005 to 2020. The data set covers peak period of kinnow that is from October to March. Four markets were chosen purposively on the basis of annual market arrivals of Punjab *viz*. Abohar, Amritsar, Hoshiarpur and Ludhiana. To meet the objectives, instability was measured by CDVI which was in different weeks for all selected markets. According to seasonality index, farmers received more than the average price between 11th to 16th weeks of the year. Correlation analysis showed that markets moved together and were well integrated meaning the price differential in these markets was not more than transportation cost, implying that they were efficient markets. The price series in the selected markets were stationary and unrestricted. Co-integration test indicated that kinnow prices in the selected markets had long run relationship. The speed of adjustment was low (4%) in Abohar and Hoshiarpur markets and high in Amritsar and Ludhiana markets (26% and 12%). Granger causality test revealed that Abohar market was the key market which influenced the price of the other selected markets. When standard deviation shock was given to Abohar market, an immediate and a high response was noticed in all other markets. The variance decomposition revealed that Abohar was showing strong influence right from the short run period into the future.

Growth and price performance of major seed spices in Rajasthan

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The uncertainty in production and supply of seed spices leads to fluctuation in their prices by seasonal and cyclical variations. The results indicated that coriander (57.02%), cumin (38.38%) and fennel (69.0%) crops were highly instable. The highest seasonal indices of arrivals and prices for coriander and cumin were found in March (358.53%), November (114.53%), October (111.29%) and April (392.98%), months respectively. In case of fenugreek and fennel, highest seasonal indices of arrivals and price were observed in the month of May (240.18%) December (110.95%), April (590.71%) and August (122.03%), respectively. The lowest variability was reported for fenugreek (6.32%) and fennel (12.27%) in Jodhpur market.

Production scenario and performance of Indian spices trade - An economic analysis

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India is referred to as the land of spices. India is also a large exporter of chilli, turmeric, cumin, pepper and other spices and it also imports several spices such as cardamom, ginger, coriander, poppy seed, garlic, cassia, etc. to meet its requirement Andhra Pradesh is the largest spice producing state in India. Gujarat, Karnataka, Rajasthan, Tamil Nadu, Assam, Kerala, Madhya Pradesh, Maharashtra, Odisha, Uttar Pradesh and West Bengal are the other major spices producing states in India. Most of our spices are exported to West European countries and North American countries. In the world, there is 3.19 % growth rate in estimated demand for spices. But, India's growth in spices export is reasonable but not remarkable. This study utilizes the secondary data collected from different sources like Spices Board of India, Export Statistics for Agro and Food products, Department of Horticulture, Bangalore and the the websites of Agricultural Processed Products Export Development Authority (APEDA) and Food and Agricultural Organization (FAO).The data collected pertains to the period 1985-86 to 2015-16. The change in production was found to be the highest for coriander (36.68%) followed by pepper (35.66 %), fenugreek (18.15 %), cardamom (11.75 %), chillies (9.30 %) and ginger (5.71 %). As far as the export was concerned Vietnam was importing majority of the spices from India followed by Indonesia, U.S.A, Malaysia, U.A.E, United Kingdom and Saudi Arabia. However, India imported the spices mainly from Nigeria, Afghanistan, Indonesia, Burma, Nepal, Pakistan, Vietnam, Ethiopia and China. The biggest handicaps that Indian spices face in the international market are the high cost of the product and high level of microbial contaminants including myco-toxin in the finished product. We need to make concerted efforts for producing clean spices at competitive prices. India can withstand the competition only by increasing productivity and reducing cost of cultivation leading to low cost per unit of production.

Lessons not learnt: Onion prices

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This paper looks at the phenomenon of sharp spikes in onion prices almost every alternate year. The paper shows that acreage and production of onions have increased over years, thus there seems to be no problem of supply shortages. The shortages are created by some weather event, which leads to onion shortages that do not last for more than 3-4 months. To get over this problem, government usually resorts to instant export bans, jacking up of minimum export price and strict implementation of storage limits. The paper shows that this hurts India's exports. It gives some recommendations to deal with the situation better.

Competitive performance of agricultural commodities in world agricultural market: A revealed symmetric comparative advantage approach

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This paper seeks to quantify the extent to which India has a comparative advantage in export of major 35 agricultural commodities. It is based on secondary data for the period 2007-2016. The result of study revealed that the values of RSCA for rice were negative during in all the years and more or less stable (-0.9). The negative RSCA indicated that comparative disadvantage in India's rice exports. India had enjoyed a revealed symmetrical comparative advantage in dried lentil, dried chickpea, and groundnut exports but had depicted a declining after 2011. In guargum, groundnut, and walnut more or less stable RSCA observed during the entire period. India had comparative advantage in fresh grapes exports to world has been increasing from 2010 to 2013 but thereafter started to decline and reached negative in 2016 (-0.07). India had comparative disadvantage in export of fresh fruits citrus except the year 2011 (0.26).

Spatial price integration and price transmission among major cotton (kapas) markets in south India

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Market integration and prices in commercial crops like cotton (kapas) play an important role in determining the production decisions of the farmers and diversification to high value crops. In this context, the present study explores extent of market integration and price transmission in selected cotton (kapas) markets in southern states of India using Johansen co-integration, Vector Error Correction Model and Granger causality test. The study used monthly prices data of cotton (kapas) sourced from selected markets of Adoni, Bijapur, Warangal and Virudhunagar spanning January, 1990 to December, 2019. The results of the study strongly buttressed the existence of co-integration and interdependence of selected cotton (kapas) markets. However, the speed of adjustment of the prices found to be moderate in Adoni and Bijapur and quite weaker in Virudhunagar market and thereby prices correct a small percentage of the disequilibrium in these markets with the greatest percentage by the external and internal forces. So, it necessitates the need for future research, to investigate the influence of external and internal factors such as market infrastructure, Government policy and self-sufficient production, product characteristics and utilization towards market integration. There exists bidirectional causality between Adoni and Bijapur and between Virudhunagar and Warangal markets and unidirectional causality from Adoni to

Virudhunagar, Bijapur to Warangal and Bijapur to Virudhunagar. Warangal market does not granger cause price formation in any of the other selected markets. It calls for strengthening the information technology for flow of market information regularly to help the farmers for increasing their income.

Structural transformation of agriculture in Himachal Pradesh

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This paper examines the extent and pattern of structural transformation taking place in agriculture of a predominantly rural and hill state of Himachal Pradesh. It throws light on the distribution of the land among different class sizes as well as social groups and examines the extent and source of inequality in the distribution of landholdings in Himachal Pradesh. Further, an attempt is made to know the contribution of agrarian, technological, and infrastructural variables in the growth of agriculture in the state. Similar to the trend visible at the all-India level, the marginalization of land is taking place in the state. The average size of land is consistently decreasing in the state in every agriculture census and the average size has recoded about thirty five percent decline since the inception of the state in the early 1970s. At the same time, the inequality in the distribution of land is widening in the state. Moreover, the skewness in land ownership is also increasing within the social groups as well. The schedule caste group does not qualify for the medium and large farmers in the state owing to very small size of the land they possess. The highest inequality in the land distribution has been observed among the social group scheduled tribe and over a decade interval this group exhibited a maximum increase in the inequality in land distribution.

A study on marketing aspects of paddy crop in Auraiya district of western U.P.

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The study was undertaken in Auraiya district of Uttar Pradesh to examine the marketed surplus, disposal pattern, consumer price shared and price spread by the paddy growers. A sample of 100 farmers of Auraiya district (Uttar Pradesh) was selected from 10 villages of two blocks for the year 2013-14. The major volume of paddy was sold in Bidhuna, market of Auraiya. For the study of marketing aspects, 25village agents were randomly selected from the market. Three marketing channels were prevalent for disposal of maize in the study area viz; (1) Producer-

Consumer, (2) Producer - Village trader - Consumer and (3) Producer - Village trader - Wholesaler - Retailer – Consumer.Net price received by producer was observed higher in channel-I, followed by channel-II and channel-III which revealed inverse relationship between net price received by producer's and number of intermediaries. The channel-I producers net share in consumer price is a 95.66%, marketing cost of producer 4.34%. Producers net share in consumer price is a 90.34%, marketing cost of producer 1.93% and village trader 3.48% in channel-II, respectively. The margin of village trader in channel -II was 4.24%. In channel -III producer net price share in consumer rupee is 74.86%, marketing cost of producer 2.14%, village trader 3.16%, wholesaler 6.86%, and retailer was 2.99%; and margin was 3.67% for village trader, 3.56% for wholesaler and 2.76% for retailer. The marketing efficiency of paddy under Channel-I was found more efficient as compared to Channel-II and Channel III. It was happened due to negligible number of middleman in Channel-I. Paddy crops are profitable enterprise or farming for the farmer's in the study area and can help the farmers in the way of doubling their income and higher profits when they sold their paddy produce through governments' direct procurement centers.

Economic analysis and mechanization index of agricultural crops in Mandi district of Himachal Pradesh

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This study assesses the economic analysis of agricultural mechanization in mid hill zone of Himachal Pradesh was conducted in Mandi district of Himachal Pradesh. A sample of 60 farmers was selected randomly from 10 villages of Gopalpur and Balh blocks in Mandi district. The results revealed that mechanization index at overall farm category was 0.26 which varied from 0.21 to 0.53 among different categories of farms. The highest (0.53) farm mechanization index was found in medium farms and lowest (0.21) in marginal farms. It can further be observed that coefficient of variation was highest (39.00 %) in marginal farms and lowest (6.52 %) in medium farms. At the overall level, 46.15 per cent variation was found in farm mechanization.

Status of land use pattern in Himachal Pradesh

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The present study was undertaken with the broad objectives viz. to study the temporal changes in land use and to estimate trends in different land use categories in Himachal Pradesh. For this, secondary data on land use statistics for 45 year's period from 1974-75 to 2016-17 were collected from different publication of Government of India.

For observing decadal changes, the data were grouped under four period viz. period I (1974-75 to 1988-89), period II (1989-90 to 2003-04), period III (2004-05-2016-17) and overall period (1974-75 to 2016-17). The findings of the study showed that the proportion of area under forest has increased from 21.75% in 1974-75 to 29.77% in 1990-91, after that it declined to 24.61% during 2016-17. The proportion of net sown area to the total area has declined from 18.85% in 1974-75 to 11.85% in 2010-11, after that it rises marginally to 12% in 2016-17. It was observed that the area under culturable waste declined by 0.51% and barren land increased by 5.73% whereas, land put to non-agricultural uses increased by 2.38% and net sown area has significantly decreased at the rate of 0.13% per annum during the overall period. It can also be noticed that period III has lowest level of variability in all categories of land compared to periods I and period II. Inter-sectoral land budgeting revealed that area shift were occurring from both desirable and undesirable ecology sectors towards agricultural as well as non-agricultural sectors.

Growth performance and potential of sugarcane production and sugar export

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Agriculture is one of the most important sectors of the Indian economy which occupied about 43% of geographical area and contributes about 14% of the GDP. India is one among the major sugar producers of the world by producing 300 million tonnes of cane per year. Uttar Pradesh is one of among the major sugarcane producing state of the country. These background information shows the importance of the crop and trend analysis of sugarcane production productivity and area become important. The analysis based on secondary data for twenty years included the measurement of annual growth rate, compound growth rate, coefficient of variation in area, production and productivity of sugarcane. The study considered the data related with five major cane producing states i.e. Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh. The result of the study shows that growth rate and instability were directly related in the area, production and productivity of sugarcane.

Contribution of agricultural credit towards productivity in paddy, cotton and maize

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The institutional credit extended for marginal and small farmers resulted in increased yields of paddy, cotton and maize, which was established by the significantly higher yields registered by loanee farmers when compared to

non-loanee farmers. Alternativey, to understand the contribution of credit to the productivity is by introducing dummy variable in the functional analysis. In paddy, credit is a positive factor increasing productivity by 0.04% at 0.05% probability level. Regression coefficient of credit was highly significant for cotton. Credit again contributed positively to maize yield also and was found to be capital intensive crop.

Farm profitability, potential and price integration for green pea markets in Punjab

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Present study was attempted to workout profitability of green pea crop in Punjab and analyzed the extent of price integration among the spatially separated markets using both primary and secondary data. The results of the study have confirmed profitable gross returns and presence of cointegration, implying the price transmission among markets. To get further evidences as to whether and in which direction price transmission is occurring between the markets pairs, Granger causality test has confirmed Amritsar to be the price-determining market. A shock originating from the Amritsar wholesale market is more or less transmitted to all other major green pea markets in the state confirming the its dominance in price determination. It was found that when a standard deviation shock was given to any market, the responses of all other markets disappear between 1 and 2 months. This could be due to role of modern technology and internet facilities but still, the difference in prices in different markets leaves farmers at price risk. Study suggested improvement of the information precision to envisage the price movements used by marketing operators for their strategies.

Price discovery mechanism in unified market platform (UMP): A case study of APMC, Raichur

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Agricultural marketing plays a crucial role in economic development. An efficient marketing system is one which minimizes the costs and maximizes the producers share in consumer's rupee. Agricultural markets in India are characterized by poor competitiveness and poor price discovery. In order to provide better price to the farmer transparent price discovery mechanism is the need of the hour. The present paper attempts to analyze how price will be discovered in e-tendering at trader level. Unveiled the Factors influencing the price like no. of bids per lot, lot size and quality parameters through Regression analysis. It indicated that numbers of bids per lot and lot size have positive effect; moisture content has negative effect on prices.

Performance of e-NAM in Telangana - A case study of Kesamudram market

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Agricultural markets in India are characterized by poor competitiveness, presence of excessive middlemen, poor competition and multiplicity of market charges, reduced marketing efficiency and poor price discovery. In order to eliminate the deficiencies in the existing marketing structure, and to integrate markets over space the Government of India introduced a new scheme called e-National agricultural market (e-NAM), to bring transparency and improve efficiency in the agricultural marketing for the benefit of the farmers and other market participants. The present paper attempts to analyze the impact of e-NAM on arrivals and prices of commodities traded in Kesamudram market and also the factors influencing the prices of paddy in this market With the introduction of e-NAM , both the prices and arrivals have increased in paddy and maize , while in cotton and groundnut prices have increased but arrivals were decreased during post e-NAM period. The prices of paddy were found positively correlated with number of lots, number of bids per lot, lot size, and negatively correlated with assaying parameters namely moisture content, foreign matter, damaged grains.. Among the various factors influencing the prices of paddy, number of bids per lot was found positive and significantly increasing the price of paddy in Kesamudram market.

Impact of COVID-19 on wholesale and retail prices of major pulses in India

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SARS-COV-2 was traced in India in January, 2020. The pandemic has impacted almost all the sectors including agricultural sector in the country. The present paper investigates the impact of COVID-19 on both wholesale as well as retail prices of major pulses in India. The daily wholesale and retail price data on five major pulses

namely Lentil, Moong, Arhar, Urad and Gram are collected for four metro cities in India i.e. Delhi, Mumbai, Kolkata, and Hyderabad during the period January, 2019 to September, 2020 from Ministry of Consumer Affairs, Food & Public Distribution, Government of India. The Government of India declared nationwide lockdown since March, 25, to May, 31, 2020 in different phases in order to restrict the spread of the infection due to COVID-19. It is observed that, in all the markets, price of the pulses has a sharp increase during lockdown e.g. wholesale (retail) price of Arhar in Mumbai market has increased to the tune of 36% (33%) during lockdown in 2020 as compared to the same period in 2019. For Arhar, the wholesale (retail) price increase up to 4% (4.1) in Kolkata. Increase in price is found to be diverse in different pulses and markets. To incorporate the effect of lockdown on price of pulses, time series model namely Autoregressive Integrated Moving average with exogenous variable (ARIMAX) model with error following Generalized autoregressive conditional heteroscedastic (GARCH) process has been applied by incorporating lockdown dummy in both mean and variance equation. It is observed that in almost all the markets, lockdown has significant positive impact on price of the pulses whereas in few cases, it has significant impact on price volatility.

Contract farming in hybrid seed production in Central Dry Zone of Karnataka- An evaluation of farmers' preference and profitability

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This paper provides the profitability of contract farming in hybrid seed production of watermelon, muskmelon and ridge gourd crops in Sira taluk of Tumakuru district. The results of Best-Worst scale indicated that provision of input by company was the major reason for participation in contract farming by farmers. The company considered a number of factors while fixing the procurement price of hybrid seeds, viz., number of seeds/100 gm, productivity and cost of production and sale price of the hybrid seeds. The benefit per rupee of expenditure was Rs2.11, Rs 2.09 and Rs 1.81 for watermelon, muskmelon and ridge gourd respectively.

Integrated farming systems for sustainable agriculture

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Integrated farming systems play important role in increasing productivity and sustainability of agriculture. A field experiment was conducted on cultivator's field during *Kharif* and *Rabi* season of 2017-18 on medium black soil in scarcity zone of Satara district in Western Maharashtra. The diversification is carried on farmer's field by

replacing existing cultivar by university released varieties and technologies. In Phaltan and Khandala blocks of Satara district four types of farming systems viz., Crop + Dairy + Goatery + Poultry, Crop + Dairy + Goatery, Crop + Dairy + Poultry and Crop +Dairy were identified. The major cropping systems were Green gram - Chickpea. The crop+dairy+goater+ poultry yielded the highest returns with a benefit-cost ratio of 2.14.

Scaling scan for sustainable and intensified agricultural production in Andhra Pradesh

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The number of farm holdings in Andhra Pradesh have increased resulting in reduction of average holding size. The organization of the already existing unemployed along with the returned migrant labor into cultivation cooperatives or farmer producer organizations, provision of training in production of agricultural and allied agricultural products, linking these activities with already existing government programmes and schemes could be the action plan to achieve sustainable and comprehensive food and nutritional security in addition to create additional employment opportunities in the rural areas. The Scaling Scan, a tool developed by PPP Lab and the International Maize and Wheat Improvement Center (CIMMYT) in 2017 was used to identify the critical areas that need attention for sustained and intensified agricultural production in Andhra Pradesh. The results revealed that value chain, finance, collaboration, leadership and management are the scaling ingredients that scored less requiring overcoming several challenges in reaching the ambition of sustainable and intensified agricultural production in the state of Andhra Pradesh.

Economics of capsicum cultivation under protected condition in South Gujarat Region

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Protected farming of vegetables is economically more viable. Adoption of protected cultivation technology can improve yield and productivity of capsicum in off-season. Growing of capsicum in greenhouses is proving to be a very remunerative. Cost is the major issue in sustaining this technology. The present study examined the economic feasibility and profitability of capsicum cultivation. Data were generated by cost accounting method for estimating the feasibility of production and was analyzed by using project evaluation techniques such as

Benefit Cost Ratio (BCR), Net Present Value (NPV) and Internal Rate of Return (IRR) and Pay Back Period(PBP).The present study showed that the establishment cost of polyhouse and cost of cultivation of capsicum in polyhouse for the area of 1000 $m^2$was less with 65% and 75% subsidy. Net return obtained without subsidy of capsicum cultivation in polyhouse was less as compare to the net return obtained with 65% and 75% subsidy. The higher values of NPW, IRR and BC ratio and lowest value of payback period of capsicum cultivation in polyhouse with subsidy implied that the capsicum cultivation was most profitable and economically feasible with 65% and 75% subsidy.

Greenhouse gases, emission taxes, emission indices and their mechanisms with special reference to rice cultivation in India

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Emitters of GHGs do not face full cost insinuations of their actions. Rice cultivation is a source of externality in the form of methane and nitrous oxide emissions. Price internalization of this externality was done by taxing emissions at carbon prices. Emission indices were obtained calculating emission coefficients to address the intensity of emissions in different regions. Emission taxes negatively impacted rice supply function and led to increase in its prices both at market prices and shadow prices of carbon. Emission taxes being components of cost of cultivation result in price variations. To minimize the impact of emission taxes producers can be motivated to adopt alternative cultivation practices that reduce GHG emission.

Indian rice exports and virtual water trade: The trade - off between economic gains and environmental concerns

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This paper makes an assessment of water footprint in production and export of rice in India. Global footprint of rice production was 235774 mm^3 per ton which was 53% of GRWF, 41% of BWF and 6% of GYWF for 2018-19. The virtual water flows in trade was 24354 mm^3/year and the percolation was 16924 mm^3/year. The share of basmati and non-basmati trade accounted was 16 and 42 per cent respectively. Virtual water trade in rice can be minimized by exporting less water demand and high-value crops, proper water harvesting structures and other agronomic practices.

Sanitary and phytosanitary measures for Indian shrimp exports

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Shrimp is the highest foreign exchange-earner in marine exports from India. It is a key contributor to the seafood export basket, accounting for 41% of quantity and 68.46% of the total earnings. During the period 1995-96 through 2017-18 significant positive growth rate was observed in shrimp exports of 7.03% in quantity 10.73% in value. Sanitary and Phytosanitary (SPS) issues have an increasing significance in the context of international trade. The significance and importance of food safety and quality assurance hit the Indian shrimp exporters. During 2014 to 2018 the Furazolidone is the major cuase of rejection for exports in Japan markets. There are 316 rejections from FDA of US from shrimp exports of India during 2014 to 2018. These refusals were due to microbiological contaminations like the presence of Salmonella bacteria followed by antibiotics. The EU market shows the RASFF notifications towards the indian shrimp exports for the rejection of 250 shrimp consignments during the years of 2015-16 to 2017-18.

Building climate resilience to coastal agro-ecosystems in East Godavari

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Andhra Pradesh has a long coastline of 974 km. Land degradation has been continuous phenomenon affecting agriculture apart from high temperatures and variability of rainfall. The rise in sea level is a major threat to the in coastal areas. Due to global warming there will be increase in temperature of the earth and thermal expansion of water leads to a rise in sea water level. Sea rise results in ingress of sweet water resources with salt water. Embankments and bunds are to be erected for protecting sweet water from the ingress of sea water and other saline waters. A global sea level rise of 102 mm per year is anticipated as a result of human induced global warming. The sea water has reportedly crossed over 150-meter distance and disturbs the people near the coast. Very little work has so far been done on finding suitable practices to with stand the effects of climate change. The climate resilient practices required to withstand soil salinity, water scarcity, soil fertility, farming systems are examined for maximizing farm income. The farmers who are dependent on the ground water face a serious problem of soil salinity and loss of cultivating lands. East Godavari district has long coastline which is under threat requires restoration with existing patches of coastal vegetation. Coastal systems is requires improvement in biodiversity, wind breaks, pollution free industries, salt-tolerant rice varieties that are capable of growing in saline conditions to improve food security.

A tool to assess impact of watershed interventions for integrated management of drylands in Karnataka

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Efficient use of available water resources is vital for sustainable agriculture development. Watershed development primarily promotes soil and water conservation. A study was undertaken in 6 watershed villages of Karnataka, India in 2019 to assess the impact of watershed interventions on agriculture. Watershed Impact Index (WII) was constructed using Guilford Normalized Rank Method and five indicators emerged as important. Data were collected from 120 randomly selected farmers and analysed using paired t-test, Pearson correlation coefficient and multiple regression analysis. Significant change was observed in dairy income, ground water level, cropping intensity, milk yield and social participation. Land holding (0.421), extension contact (0.389), dairy income (0.545) and milk yield (0.510) had moderate correlation with the index value. As water management will be a critical component in future agriculture, the findings of this study would serve as a source of information for better extension planning.

Climate variability impacts on agricultural production and farmers' adaptation: A micro level study into agro-climatic zones of Tamil Nadu, India

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Recent decades climate variability pose a challenge to the world's agricultural and natural resource systems, which are already finding it difficult to cope with the growing food demand driven by population growth and higher purchasing power in developing countries. The challenge compounded by the uncertainty and pace of climate variability and its regional effects. It has been increasingly evident that climate variability affects agricultural productivity. Changes in temperature and precipitation will require farmers to adapt, but precisely where and how much is uncertain. In this context, the study examined the effect of climate variability on agriculture for the period of 980-1981 to 2009-2010 and predicted climate variables effect on agriculture production for the year of 2030 and also documented farmers adaptation practices by pre-tested interview scheduled in most vulnerable agro-climatic zones of Tamil Nadu. A Just-Pope production function (1978) was specified to analyze the impact of climate change on average yield and variance of major crops. The results showed that temperature had a positive significant influence on yield of paddy, maize, sugarcane and cotton, while it had negative influence on groundnut. The variance in temperature had positive influence on the yield of banana. Rainfall had a positive

influence on sorghum, bajra, cotton and pulses and negative on maize. Precipitation intensity had negative influence on all crops. If temperature increases, the variance in productivity of paddy and groundnut increases. Similarly, if precipitation increases, the variability in productivity for sorghum and bajra decreases. Likewise, if the precipitation intensity increases, the variability in yield increases in case of paddy, bajra and sugarcane. The calculated coefficient from Just-Pope yield function and the projected climatic data from the Regional Climate Models (RCMs) were used to project the yield of crops in the year 2030. The results showed that in North East Zone, Western Zone, Cauvery Delta Zone and Southern Zone, out of nine crops, five crops would experience decrease in productivity. Similarly, in North West Zone there would be decrease in productivity for three crops (maize, cotton and pulses). In South Zone, only two crops (bajra and pulses) will have decrease in productivity. In addition to that, an attempt made to analyze the factors that influence farmers to adapt crop choice with respect to changed climate condition, by estimating a Multinomial Logit Model. The primary data collected from the sample respondents during the months of January and February 2012. The results showed that older farmers were more likely to select groundnut, sorghum and less likely to select maize, fruits and vegetables. Education had positive and significant impact on growing groundnut, sorghum and chilies. Owning of livestock positively influence the probability of selection of sorghum and maize. The own prices of sorghum and groundnut are significant and positive as expected. Farmers are more likely to choose these crops when the market prices are higher. When non-farm income increases, farmers are most likely to prefer sorghum, cotton, maize and groundnut. When temperature increases by 1^{o}C, farmers tend to choose maize, cotton, fruits and vegetables less often while the farmer chooses pulses, sorghum, chilli and groundnut more often. If precipitation increases by 1 cm, farmers move away from sorghum, chilli, Groundnut to pulses, maize, cotton, fruits and vegetable. Hence, local government policies and programs in agriculture should have a built in component to address the climate change issues.

Multidimensional framework for measuring sustainability and resilience of farming systems

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Natural resources, are fundamental for the structure and function of agricultural systems and for social and environmental sustainability in support of life on earth. Historically, global agricultural development has been narrowly focused on increased productivity rather than on a more holistic integration of natural resource management with food and nutritional security. Now it is strongly suggested that a holistic, or systems-oriented approach, will be needed to address the intractable challenges associated with the complexity of food and other production systems in different ecologies, locations and cultures. In the present study we have developed and piloted a multidimensional framework for assessing farming systems sustainability and resilience (FSSR). The quantification framework is easily measurable and comparable across farm households, farming systems and beyond. It considers five major domains of the farming systems namely environmental, economic, productivity, social and human well-being. In the subsequent stages of measurement each domain is divided into different themes, then sub-themes and indicators. The indicators in our study have been finalized with rounds of stakeholders' consultations involving farmers, researches, development experts besides literature. Finally, we identified a total

of 115 indicators: environmental (34), economic (29), productivity (12), social (25) and human well-being (15) in the final framework which are measurable and would be able to provide an index value representing level of sustainability of farming systems at different scales: farm household, domain and farming system considering appropriate weights of different domains. The FSSR framework could be a very useful tool for designing the context specific strategies to address farm sustainability challenges.

Sustainable groundwater resource management in micro watersheds: Empirical evidence from Raichur district, Karnataka

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Groundwater is a strategic resource due to its high quality and perennial availability. However, groundwater management all over the world often lacks sustainability as evidenced by falling water tables, drying wetlands, increasing sea-water intrusion and general deteriorate on of water quality, as groundwater cannot be renewed artificially on a large scale, sustainable management of this resource is vital. They include methods for the determination of groundwater recharge, groundwater modelling including the estimation of its uncertainty, and the interfacing to the socio-economic field. The study has made an modest attempt in two micro watersheds in Raichur district, where Sujala–III watershed development program is being implemented by the Watershed Development Department, Govt. of Karnataka. Study has adopted the new approach in collection of data and information such as irrigation wells location using GPS and installation of water meters for measuring water extraction and estimation of electricity consumption by irrigation wells with installation of electric meters. Water budget technique was employed to analyze the sustainability of groundwater at micro watershed level. Results shows that groundwater use efficiency is more in onion (Rs. 810/acre inch) followed by maize (Rs. 638/acre inch), groundnut (Rs. 386/acre inch), Jowar (Rs. 187/acre inch), and bajra (Rs. 166/acre inch). Efforts should be made to include groundwater management as a one of the important component in watershed development programmes. In order regulate and efficient and sustainable management of groundwater use at micro/ sub watershed, it is need for policy for recording location(by GPS) and yield(inbuilt water meters in IP Sets) of all wells at micro watershed level.

Factors influencing the agricultural sustainability: District and farm level analysis

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This study examined the factors influencing agricultural sustainability both at regional and farm level by constructing agricultural sustainability index for North Eastern Karnataka region. Multiple Linear Regression analysis was used to know the influence of independent variables on agricultural sustainability both at district

and farm level. The regression coefficient of food grain yield, milk production, net sown area, labor force participation rate, literacy rate, households electrified, number of commercial banks, number of primary health centers, proportion of geographical area under forest, cropping intensity, livestock population and annual groundwater availability have showed positive and significant influence on agricultural sustainability at district level. However, the factors population density, percentage of population below poverty line, infant mortality rate and fertilizer consumption have a negative and significant influence on agricultural sustainability. While the factors such as farm income, livestock possession, type of land, number of crops cultivated were significantly influenced factors of farm level agricultural sustainability in the study area. Hence, the study suggests enhancing the food grain yield and increasing the milk production, area under forest, cropping intensity, livestock population and groundwater availability there is a scope for improving agricultural sustainability at the district level. At the farm level in place of mono cropping cultivation of more crops will improve the soil fertility and income in turn the agricultural sustainability of farmers.

Financial feasibility on restoration of tanks under Mission Kakatiya and its impact on farm income

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The study has presented the costs and benefits of tank restoration and financial feasibility of investment in tank restoration and benefits accrued to farmers after restoration under Mission Kakatiya in the selected two tank systems each in Nalgonda and Warangal districts of Telangana state. The total investment spent to undertake restoration works which includes de silting, repairing of sluice and weir, strengthening of bunds, etc. The cropping intensity was relatively higher (186.05 %) in case of sample farms with tank as compared to without tank (125.22 %). The benefits of silt application in the field have positive impact on crop yields. The investment analysis has revealed a positive NPW, B:C ratio greater than unity and IRR was more than the opportunity cost of capital in both the restored tanks indicated economic feasibility of tank restoration.

A district level analysis of climate change impact on crop productivity in India

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Climate change challenges the sustainability of agriculture and food security in India. The policy planning related to sustainable food systems and agriculture has to consider the possible yield impacts of climate change on major crops preferably at a spatially disaggregated level for better targeting. This paper analysed climate

change impacts at district level for major food crops using the district level climate projections for two time periods viz., mid-century (2021-50) and end-century (2071-98). Yields of most crops are projected to decrease in a majority of districts during mid-century period. The yield impacts are deeper and wider during end-century period. The yield impacts are relatively smaller and even positive in case of rapeseed & mustard and soybean. In order to overcome the negative impacts of climate change, agricultural research and extension should be supported to factor in changing climate into their research portfolio more deeply.

Assessment of irrigation water use efficiency under Ramthal Micro-Irrigation Project in Bagalkot district of Karnataka - An economic analysis

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The study analysed water use efficiency under drip and Canal irrigation situations in Ramthal micro-irrigation project area. Total sample size was 120 farmers, 60 each owning drip irrigated farms (DIF) and canal irrigated farms (CIF). Results revealed that, implementation of the project ensured higher yield and net returns from major crops cultivated in DIF compared to CIF. Agronomic water productivity and economic water productivity of major crops were higher in DIF compared to CIF, ranging from 36 percent in green gram to 78 percent in chilli and from 59 percent in jowar to 84 percent in onion, respectively.

Impact of treated sewage water from KCVP project on farm economy in Kolar district of Karnataka

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The study was conducted with a total sample of 120 farmers, with 60 each from the project area (KCVP) and control area (NKCVP). Descriptive Statistics and Crop Diversification Indices were employed to analyze the data. The results revealed that, project implementation changed the cropping pattern (Simpsons index value of 0.85 in KCVP and 0.77 in NKCVP). Income realized and employment generated by KCVP farmers was 23% and 4 % higher, respectively, than NKCVP farmers.

Status and drivers of groundwater extraction in India

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This paper analyses the status and drivers of groundwater extraction using a panel of district-level data for the most recent period. Our findings showed that the unsustainable groundwater depletion in north western states coexists with the under-utilization in eastern states of the country. The panel data analysis revealed that factors such as tube-well density, proportion of electrified tube-wells, irrigation coverage and cropping intensity have a significant positive influence on rate of groundwater extraction. The rate of groundwater extraction is low in districts where the surface irrigation is dominant. Districts with poor rainfall had higher rate of groundwater exploitation. The findings of the present study provide a platform for policy reframing related to rationalizing power tariffs for groundwater irrigation, improving groundwater irrigation use efficiency and promoting water efficient cropping pattern in over-exploited districts.

Valuation of ecoservices from nitrogen fixing trees: A case study of alder-based farming system in Nagaland

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This study was conducted to measure the monetary value of the eco services provided by the alder-based farming system (AFS) at Khonoma village under Kohima district in Nagaland by covering 60 AFS and 39 non-AFS farms. Direct market price and preventive expenditure method under the revealed preference approach was used to measure the economic value of the services provided by the system. The estimated value of the nitrogen (N) contributed naturally by the alder trees was ¹ 3208.95/farm and ¹ 7073.70/ha. The total value of the services provided by the alder trees at Khonoma ranged from ¹ 14936.81/farm to ¹ 17169.61/farm and ¹ 30521.59/ha to ¹ 35171.82/ha. Thus, the AFS has the potential to be replicated in other *jhum* areas through dissemination of knowledge on alder tree management.

More crop per drop and economic water productivity - Implications for sustainable groundwater irrigation in Karnataka and Punjab

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Using economic crop productivity and *More Crop Per Drop*, crops maximizing net returns to groundwater are recommended for Karnataka. The highest net return per rupee were from low water – high value crops of Marigold (Rs1.89), Mulberry (Rs 1.63), Chrysanthemum (Rs 1.30), Palak (Rs 1.21), Papaya (Rs 1.10); and from high water – low value Capsicum (Rs 0.35), Cabbage (Rs 0.15), Tomato (Rs 0.13), Rose (Rs 0.10), Ginger (Rs 0.10), Grapes (Rs 0.10). With lower groundwater resource and holding than Punjab farms, Karnataka farmers realized impressive net returns of Rs 5 lakhs per farm, Rs 1 lakh per acre and Rs 80,000 per capita. Punjab has immense opportunity for sustainable use by diversification. Role of extension exposure visits is immense to prevent Punjab from predicament of further depletion of groundwater.

Sustainability of organic farming: Implications from organic paddy cultivation in Karnataka

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The present paper on comparative economic analysis of Organic Farming (OF) and Conventional Farming (CF) in paddy cultivation using data from 60 farmers revealed a total transition cost of Rs.7361 in shifting to organic paddy. The per acre gross returns were 23 percent higher under OF (Rs.61,923) than CF (Rs.47,463), without much difference in the total cost of cultivation. Lower yield (14.75%) under OF was compensated by higher price (34.75%) realisation and gave higher returns per rupee of expenditure under OF (Rs.1.58) compared to CF (Rs.1.23). The PSCR for paddy grown under OF (38.88%) was less compared to CF (40.93%).

Economic analysis of groundwater market for irrigation in Karnataka

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This paper mainly focused on economics of groundwater markets for irrigation in Karnataka. Results indicated that groundwater markets have not only improved groundwater access and enhanced income levels of farmers, but also increased irrigation costs due to reduced water table and high probability of well failure. Net return per acre inch of groundwater and net return per rupee of irrigation cost was high for water buying farmers followed by water selling farmers and control farmers. Multinomial logit results indicated that water buying and water selling decisions are being influenced by farm size, family size, land fragments, water cost and agricultural credit. Such information is crucial for the policy makers while framing policies towards groundwater markets.

Willingness to pay for tank management through water user associations in Warangal district of Telangana: A double bound contingent valuation approach

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Water scarcity has become a serious limiting factor for agricultural sustainability in the world. The myopic overuse of water resources and climate change has been the driving forces of dwindling water resources. Collective action through involvement of community is suggested as one of the measures for effective management of water resources. With the Government of Telangana investing heavily to save its tank irrigation system through its flagship program 'Mission Kakatiya', we examine the option of establishing Water User Association for managing the tanks locally. We estimate the willingness to pay using rigorous econometric method of double bound contingent valuation and found that farmers are willing to contribute Rs700/ acre/ year towards managing tanks through water user associations. We also examined the factors influencing farmer's willingness to pay and found that land owned, the major crop and previous experience of working in water user association affects the farmers willingness to pay. The findings are suggestive that it is a good policy option to involve farmer participation in the management of tanks through water use association in synergy with government efforts to revive the tank irrigation system in Telangana.

Economics of Pineapple production in Maharashtra and Kerala: A comparative analysis

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This study analyzes the economics of pineapple production by tenant cultivators of Maharashtra and Kerala. The results show a 21% higher cost of cultivation in Kerala than in Maharashtra. The reason for the same is the higher input cost incurred by tenant cultivators in Kerala. Higher lease rent and labor wage have significantly augmented the cost of cultivation of pineapple in Kerala. Direct marketing channels are identified for pineapple in Kerala whereas the marketing channels are indirect in Maharashtra. The study reveals that although pineapple cultivation in leased-in lands is remunerative for growers but more for those in Maharashtra.

An empirical assessment of productivity, farm income and stakeholders' perceptions of onion crop cultivation and its trade in Maharashtra

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Although the diverse agro-climatic conditions enable India to produce onion in many parts round the year, most of the onion produced in the country still comes from the state of Maharashtra. Onion in Maharashtra is cultivated in both kharif and rabi seasons, and the production as well area under the crop has been steadily growing over time. However, the crucial questions that need to be answered revolve around not only the economics of onion cultivation but the productivity variations for different varieties of onion, and the stakeholder's perceptions regarding production and marketing of this crop. Results show highly profitable nature of onion crop. Rabi onion, in particular, showed much higher returns. Farmers allocated 126.17% more area to rabi onion. Longer shelf life, better quality of produce, higher productivity and reasonably higher prices on offer were the major reasons for higher allocation. On the other hand, the variations in profit were seen on account of productivity differences, cost structure and prices received by the farmers for various varieties. Although onion crop cultivation was found to be lucrative proposition, the farmers were seen to confront with number of problems, which mainly revolved around high price fluctuations due to lack of rain, un-seasonal or excess rain, lack of remunerative price, lack of government support/procurement, etc. The other stakeholders encompassing wholesalers, retailers and exporters encountered with problems like poor quality of supply, competition from other traders, poor facilities of drier, poor road network, poor port facilities, export policy uncertainty, mixing of different varieties, problem of chemical residue, etc. Since rabi onion has much longer shelf life, it is felt that the government intervention and support is necessary for rabi onion, which will not only protect farmers but also consumers.

Seed production in cowpea: An economic viability study

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The present study is focused on the cowpea seed production in Palakkad district of Kerala. Registered seed farmers in VFPCK were selected for the study. Average cost of cultivation for cowpea seed production for Vellayani Jyothika variety was high. Cobb-Douglas production function revealed that the labor contributed significantly towards increase in yield. The quantity of plant protection chemicals indicated excess utilization. The factors affecting availability of quality seed were pests and diseases attack and costs of production of different cowpea varieties. High cost of input seed and high wages were the major constraints faced by the cowpea farmers.

Growth in vegetable area, production and productivity in India: A futuristic insight

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This study was conducted to analyze the growth in vegetable area, production and productivity across different states and to forecast the future values with the existing growth pattern of vegetables in India. Vegetable area, production and productivity have grown at the rate of 2.17 %, 4.29 % and 2.07 %, respectively from 1961-62 to 2017-18. Vegetable production may increase 1.75 folds from 197.17Mt by 2020, 242.99Mt by 2030, 284.7 Mt by 2040 and 322.64 Mt by 2050. Vegetable productivity has increased by 2.75 folds from 1961-62 (6.64 t/ha) to 2017-18 (18.29 t/ha) and it may rise by another 1.29 folds from 2018-19 to 2050-51. There would be a surplus production of vegetables in the coming years if the same scenario of growth prevails, ranging from 75 to 133 million tons during 2030-2050. The highest significant growth in acreage under vegetable cultivation was witnessed in Nagaland (21.51 %) followed by Madhya Pradesh (16.05 %), Mizoram (15.13 %) and Manipur (12.76 %), whereas the highest significant growth rate in vegetable production was seen in Nagaland (30.79 %) followed by Madhya Pradesh (22.38 %) and Tripura (10.57 %). Vegetable productivity was found highly instable in Mizoram (37.30), Rajasthan (23.27) and Kerala (22.30).

Growth performance and instability of castor cake export from India

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The growth rate of value of castor cake export was found the highest (37.59%) followed by growth rates of quantity (31.15%) and unit value (4.91%) during 2003-04 to 2017-18. However, instability in the value of castor cake exported was very high (58.03%) followed in quantity (43.89%). Looking to the stable market for castor cake export, South Korea emerged the most stable market with high probability (56%) of retention. This study revealed that India achieved remarkable growth rate in export of castor cake, but its price realization is low. As the world becoming more environmental conscious now a days, the natural manure like castor cake could find better market worldwide.

Study on growth and instability in pulses production in Bihar: A decomposition analysis

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Pulses are vital source of protein in consumer's dietary pattern. An assessment of changes in area, production and productivity of the pulse crops is considered helpful for their management and in policy making to ensure nutritional security of ever growing population. We find that the annual growth rate of production of lentil in Bihar to be much higher than other pulses at (0.20%) and that of productivity at (0.55 %) from 1985-86 to 2015-16. Instability indices for area, production and productivity of green gram were found to be 7.04, 10.84 and 9.34 respectively which were lower compared to other pulse crops grown in the state. The decomposition analysis revealed that in case of yield effect of red gram, low productivity may be due to the fact that it is mainly grown by the marginal and small farmers under rain-fed conditions with poor crop management practices. In case of gram, the results show that production was mainly influenced by the area and productivity. The study emphasized on the need for expansion of area under pulse crops and to increase their production through technological interventions.

Rice bran oil: A silver lining to Indian edible oil economy

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Edible oil is an integral part of everyday cooking; at present the annual per capita consumption of vegetable oil in India is about 19.4 kg as against 3.4 kg during 1950s. Unfortunately, the annual compound growth rate of major edible oilseeds in India went negative. This phenomenal disparity in demand and supply of vegetable oil in India bothers the country with profuse investment on overseas purchase. India being the major producer of rice, its milling yields huge amount of barn which contain up to 24% edible grade oil with superior quality profiles that could eventually reduce pressure on oilseeds crops of India.

Nutrient standardization of papaya (*Carica papaya* L.) for enhanced fruit yield and quality under homestead farming system

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Papaya has gained commercial importance over the years because of its varied uses, mainly for table purpose. It is usually grown as homestead crop in Kerala. In recent years, isolated attempts have been made by some progressive farmers for commercial cultivation. Major production constraint encountered in papaya is difficulty in maximizing yield with in unit time. The present experiment was undertaken to study the response of major plant nutrients *viz* nitrogen, phosphorus and potassium on growth, yield and quality of papaya and also to find out the optimum dose of NPK for commercial cultivation of papaya under Kerala conditions. The trial was conducted in 3^3 confounded factorial RBD, confounding NPK in replication-1 and NP^2K^2 in replication-2. Different levels of nitrogen, phosphorus and potassium (200, 250 and 300) gram per plant per year were tried in six equal splits. Results revealed that application of nitrogen, phosphorus and potassium at the rate of 250:250:500 gram per plant per year in six equal splits, at two months interval was economically viable and improved the growth, yield and quality of papaya.

Technical efficiency in finger millet and paddy crop in southern Karnataka

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This study, conducted in the southern Karnataka specifically focus on progressive (Tumakuru district) and less progressive (Ramanagara district) areas with an objective of understanding the technical efficiency of paddy and finger millet. The popular technical efficiency benchmarking tool within agricultural research are parametric (*Stochastic Frontier Analysis, SFA*) or non-parametric (*Data Envelopment Analysis, DEA*). There were no differences in mean scores of technical efficiency of paddy in progressive (0.86) and less progressive area (0.85). But in case of finger millet, progressive area farms (0.76) were technically more efficient than the less progressive farms (0.57). Eighty-three and seventy-seven percent of obtained yield and potential yield was primarily due to factors which are under the control of farmers, respectively. This clearly indicates the importance of agriculture extension in promoting adoption of technologies and its potential in improving yield and income of farmers.

Economic valuation of agro forestry systems and quantification of ecological uses in Tamil Nadu

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Traditionally, agroforestry is extensively practiced in India in the form of the shifting agriculture, a variety of cereal cropping systems, home garden systems, traditional plantation systems, etc. In recent times, many of these agroforestry systems have started breaking down for a variety of reasons. In many situations, high diversity based agroforestry systems have been replaced by low diversity simplified cash crop systems, and this is questionable in terms of sustainability. The paper argues for traditional ecological knowledge and to measure the social cost and benefit involved in agro-forestry in study area using Investment analysis, Sensitivity analysis of tree cultivation, descriptive statistics and Pearson product moment correlation (PPMC). The discounted social costs, returns, net worth for agri-silviculture system (teak+maize) were estimated to be Rs. 24208, 137457 and 113248 per hectare over the life time of teak trees. The Benefit Cost Ratio was 5.68 showing that investment in teak cultivation can be considered as substantial and economically justifiable. Internal rate of return was found to be 23% over the period. It showed that investment made in teak production is profitable, it could be seen that the intangible cost included cost of birds scaring only. It was higher in case of Teak since these crops provided shelter to birds, have a longer gestation period and they attract more birds. Intangible benefits are realized due to soil and water conservation, agricultural productivity of intercrops, nitrogen fixation, waste assimilation and carbon storage. In the socio-economic analysis, when carbon sequestration and soil water conservation benefits are incorporated, it provides very high NPVs for agri-silviculture system.

Transitions in input use and growth of total factor productivity of sugarcane in Gujarat

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This paper has analyzed the growth in TFP of sugarcane crop and trends in cost structure of sugarcane crop in Gujarat. The study revealed stagnant TFP growth at the rate of 0.43% per annum during1990-91 to 2018-19. The cost share of human labor, irrigation and miscellaneous in total cost of cultivation of sugarcane in Gujarat has shown increasing trend, whereas of the rental value of land has declined. It is suggested that technological gains have not been experienced in this crop needs concentrated efforts to bridge extension gap and further research to evolve concrete strain, resistant to pest and diseases which reduce the real cost of production.

Profitability of capsicum production under protected conditions in Punjab: Towards agri-entrepreneurship for better livelihoods

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The present study was undertaken to assess the costs and returns in the production of capsicum under protected cultivation vis-à-vis open field cultivation, to examine the economic viability of investment for the production of capsicum under protected cultivation and to identify the constraints in the production of capsicum under protected cultivation technique and making suggestions for streamlining the same. The primary data for the year 2018-19 were collected from 40 poly house and 40 open field farmers from Ludhiana and Jalandhar districts. The results revealed that the cost of establishment of polyhouse was to the tune of Rs.18,70,000/4000m^2 with subsidy. The total per acre cost of production of capsicum under polyhouse was higher by Rs.417233 (336.45%) than that of open field cultivation. The net returns under polyhouses were higher by Rs.280582.90 (510.50%) for capsicum in polyhouse cultivation. The huge differences in cost of production in polyhouse cultivation of capsicum were due to the use of more number of seedlings, costly seeds, high field and bed preparation cost and requirement of skilled labor while expenditure on weeding and irrigation was found less in polyhouse cultivation of vegetables. The yield of capsicum (111.05%) in polyhouse cultivation was found higher as compared to open field cultivation of capsicum. The cultivation of capsicum under polyhouse was found to be feasible as reflected in higher value of NPV, i.e., Rs. 17,61,915.66 per 4000m^{2}with benefit cost ratio (BCR) of 1.3 and Internal rate of return (IRR) of 24% . High investment cost, lack of technical guidance, costly seeds, non-availability of skilled labor and high cost of maintenance were the major constraints faced by polyhouse farmers. Despite these constraints, cultivation of capsicum under polyhouse emerges as a profitable venture to increase farmers' income.

A dynamic study of breakeven output, yield and land-equivalent for major crops of Madhya Pradesh

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Madhya Pradesh had been lagging behind in private investment in agriculture since 2000's. To investigate the reasons for this decline, breakeven analysis coupled with trend analysis was carried out using plot level secondary data from DES, India for the period 2000-01 to 2016-17. Data were for crops were sorghum, cotton, maize, chickpea/gram, black gram, red gram, lentil, rapeseed and mustard, soybean, paddy and wheat crops. The results of the analysis revealed that coefficient of variation for cotton, soybean and black gram was very high which makes them unsuitable for farmers with inadequate means. Lentil was the most stable crop with lowest breakeven land-equivalent which made it suitable for small and marginal farmers. Rice-wheat and cotton-gram cropping pattern was found to be risky as these set of crops had same movement over time. red gram, gram, sorghum, paddy, mustard, soybean and Black gram had horizontal trend of break-even output. Wheat was the only crop with negative trend of breakeven output. Cotton, lentil, and maize had positive trend of breakeven output. Important policy suggestions include adoption of custom hiring of machineries and rigorous yield improvement programmes for paddy, sorghum and maize.

Green mussel (*Perna viridis*) farming in India: An analysis of major growth milestones, recent decline due to disease incidence and prospects for revival

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Green mussel farming as a smallholder friendly, livelihood-enabling supplementary activity along the backwaters in the southwest coast of India is analyzed in this paper covering various phases of its adoption and growth. Though a benign enterprise that does not demand significant establishment cost and labor-intensive culture activities, green mussel production is presently at a crossroads, facing severe challenges at its very cradle, owing to various biotic and abiotic constraints. The main underlying factors are analyzed, physical and economic losses estimated, and policy options suggested to enable a steadfast revival.

Determinants of total factor productivity of milk production in eastern region of India: A farm level analysis

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The study estimates the total factor productivity (TFP) of dairy farms in eastern region of India and its determinants. The results suggest that overall total factor productivity of dairy farms in the region was 0.1697 and there is a degree of variability which could be reduced if the farmers adopt better management practices. The frequency distribution of dairy households by TFP value was positively skewed such that 97 % of the farms had TFP less than 0.30. Among all the factors included in the model, herd size, herd composition and C-P ratio had a significant impact on TFP. Thus, TFP is influenced by economies of scale, technology and management practices.

Impact assessment of ICAR-NRCSS coriander variety (ACr-1) using economic surplus model

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Coriander, the major seed spice grown in the Rajasthan, suffers from various fungal diseases, of which the stem gall is the most destructive and versatile disease causing up to 50% yield loss. ICAR-NRCSS Ajmer has released a stem gall resistant variety named Ajmer Coriander-1 (ACr-1). Present study is conducted to examine the economic impact of ACr-1 in Rajasthan state using Economic Surplus Model. Study found that the ACr-1 variety developed by the ICAR-NRCSS has performed very well as the net social benefit was 11105.83 million rupees with 15% adoption rate during the period of six years i.e. 2013-14 to 2018-19. The study suggests that the impact assessment not only ensures economic viability but also the through overview of improved variety which can be further used to improve the poor scenario of crop in the state.

Economic analysis of production, resource use efficiency of cabbage in Khandwa district of Madhya Pradesh

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Cabbage (Brassica oleracea) is one of the most popular winter vegetables grown in India. It is cultivated in 0.245 million hectares with the total production of 5.617 million metric tonnes and average productivity of 22.9 metric tonnes/hectare. Cabbage is used as salad, boiled vegetable and dehydrated vegetable as well as in cooked curries and pickles. Cabbage is rich in minerals and vitamins A, B1, B2 and C. Yield, returns and marketing costs and constraints of production and marketing data were collected from the sample farmer as well as from different market functionaries through the pre-tested schedule for the year 2016-17. The cost of cultivation, cost of production, net profit, and cost benefit ratio were worked out using standard cost and profitability concepts. The productivity of cabbage was higher in medium size group followed by small and large size group. The net return over cost C3 (total cost) observed higher in small size followed by medium and large size farm in cabbage. Family labor income was higher in small size group which tends to decline as per increase of farm size. The net return per farm was higher in small size group due to higher allocation of cabbage area and tends to decline as per increase of size farm.

A study on structure, conduct and performance of Sidlaghatta cocoon market in Karnataka state

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The functioning of Sidlaghatta Cocoon Market in Chikkaballapur district of Karnataka state was analysed by examining the trend in arrivals and prices of cocoon; structure and conduct of the market; e-auctioning process; and constraints faced by stakeholders in the market. The arrivals and prices of cocoon showed an increasing trend with CAGRs of 0.61% and 8.21%, respectively for the reference period (2003-04 to 2017-18). The cocoon market was oligopolistic in nature as the Gini concentration ratio was found to be 0.83. Though the e-auctioning process was found to be insignificant with respect to better price realisation; as a digital process, it facilitates storage and retrieval of data, and also helps in analysis of market information. The major constraint faced by farmers participating in the cocoon market was non-remunerative prices while the reelers opined that inadequate market information was the major constraint faced by them.

Economic efficiency of sunflower seed production

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Seed material is the basic and vital input in agriculture production programme and quality of seed is the major determinant of output growth, given other complementary inputs. The present study was based on primary data collected from 30 each of sunflower seed producing farmers of KBSH-44 and KBSH-53 varieties taken up by

KSSC, in Chikkaballapura district of Karnataka, during the agricultural year 2016-2017.The per hectare cost of cultivation (Rs. 1,03,329), gross return (Rs. 1,78,460), and net return (Rs. 75,131) with yield of 12.4 quintals in KBSH-53 variety seed production was inefficient than KBSH-44 variety in which the cost of cultivation, gross returns and net returns were Rs. 1,02,949, Rs. 1,90,890 and Rs. 87,941, respectively, with a yield of 13.2 quintals . Hence, production of KBSH-44 variety certified seed has resulted in a win-win situation for the farmers with higher yield and increased returns. The decision of the farmer on adoption of seed production technology was positively influenced by factors like assured market, seed subsidy, and technical guidance as measured by garrett ranking. The constraints faced by farmers in seed production were non-availability of labor, lack of pure and quality seeds.

An economic analysis of areca leaf plate manufacturing enterprise

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Arecanut (Areca catechu L.) is a commercially and socially important plantation crop in South-East Asia. Though the dry kernel is the economic part leaf sheaths which form the agro-waste are used to are used to make use and throw utensils that are eco-friendly. An empirical survey of the sample entrepreneurs in the study area of Dakshina Kannada district of Karnataka was conducted. Sixty respondents were selected by a combination of purposive, snowball and random sampling techniques. The input utilization pattern, asset position, labor utilization pattern and, costs and returns structure of the enterprise was analyzed. The enterprises yielded Rs. 778272 of net returns per annum with a B:C ratio of 2.4. Hence, it forms an economically feasible and financially viable enterprise that can replace thermocol, polythene paper and plastic plates. As a subsidiary.

Economic analysis of milk production in Madhya Pradesh

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The economic analysis of sample producer households has been presented through the costs and returns from milk production across various species. Overall total maintenance cost was the highest for crossbred cows, followed by buffalo and indigenous cattle . Variable cost accounts for the highest share in total cost of milk

production. Overall, it constitutes around 89.46, 88 and 90.75% in the case of indigenous cattle, buffalo and crossbred cows, respectively. Feed and fodder cost accounts for a major share followed by labour cost. Average milk yield per animal per day of crossbreds was higher among all the three species across all the categories of households in the state. It was found that overall average productivity of indigenous cattle, buffalo and crossbred cows were 2.83, 5.55 and 7.17 litres/day, respectively. Overall per litre cost of milk production was observed to be highest for buffalo (Rs31.85) followed by indigenous cattle (Rs30.74) and crossbred cows (Rs25.94). On an average, per litre returns from milk production accrued was highest in case of buffalo (Rs10.53) followed by crossbred cow (Rs7.33) and indigenous cattle (Rs2.43).

Technology domains of patents in Indian fisheries sector

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Through data mining, patents in Indian fisheries were extracted for year 2019. Of all filed applications 0.1% and among granted patents 0.069% were from fisheries. Fisheries post-harvest had 56.25% inventions related to fatty acids, fish oil/gelatin, chitin cholesterol extraction, phytase supplementation and drying rack. Aquaculture related 43.75% inventions were inflatable covering, cultivation with high growth, aeration device, shellfish apparatus, pearl oyster, fish culture device and pond monitoring. Indians were granted 56.25% of patents. ICAR fisheries institutes had 4 patents, 2 from Universities and 3 from companies. European countries and USA had 3 patents each and 1 was from New Zealand.

Artificial intelligence and its application in Indian agriculture : A thematic analysis

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Artificial Intelligence (AI), Machine Learning (ML), and Internet of Things (IoT) are the most frequently used words in recent technological innovations. All the technologies have a significant potential to contribute for agriculture, among them AI is more out spoken. Since AI is a relatively new technology, impact studies in agriculture are very scarce. The present study tries to fill this gap by analysing key areas of AI in agriculture with the help of a qualitative technique viz., thematic analysis, using research articles and google news articles related

to AI and agriculture. Results suggest that potential benefits of AI are more focussed on forecasting, prediction, assisting farmers, helping governments to identify beneficiaries, and grow crops in efficient manner with minimal use of inputs.

An economic analysis of capsicum production under protected cultivation in western Maharashtra

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A survey was conducted by using pre-tested interview scheduled among the farming community, producing capsicum under protected cultivation in the Western Maharashtra. The results of the study indicates that, total investment about Rs.36.17 lakhs per acre required for erecting polyhouse. The major costs of establishment were incurred on GI frame (72.78%) followed by polythene sheet cost (6.67%). The share of cost A was 46.53% in total cost of capsicum cultivation. The cost B including cost A with interest on fixed capital excluding the land was 27.04% followed by amortized cost (17.70%) and rental value of land (6.34%) of the total cost. The cost C was Rs.12,61782 per acre for capsicum under protected cultivation. The gross return of the cultivated crops found to be Rs.16,12,875 and net return of Rs.3,51,093. The cultivation of capsicum in a polyhouse was found to be highly feasible as reflected in higher values of BCR (1.28). High investment cost for establishing poly house followed by lack of technical guidance was most important constrains among the farmers in capsicum production under protected cultivation.

Economic analysis of different aquaculture systems in Mizoram

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Economic analysis of different aquaculture systems in Mizoram was performed using interview schedule from 120 farmers. Results indicated that unitary system was practiced for 8-10 months with higher cost of culture (Rs 2.93 lakh/ha). Paddy-cum-fish culture farmers received higher average net income (Rs 0.66 lakh/ha/year). B:C ratio of paddy-cum fish integrated system (1.32), pig-cum-fish integrated system (1.29), and unitary system (1.15) indicated economic feasibility and profitability in all three aquaculture systems. However, integrated fish farming was more profitable than unitary farming, and among the three systems, paddy cum fish culture was found to be the most profitable system.

Economics of Jhora fisheries in West Bengal

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Economic analysis was carried for Jhora (spring water) fisheries in Darjeeling, West Bengal by conducting interviews with 120 fish farmers having cement ponds, cement with mud bottom ponds and mud ponds. Farm business analysis and Benefit-Cost ratio revealed that major investment was towards pond construction and total investment/500 sq.ft was highest (Rs 32,033.16) for cement ponds, followed by Rs 22,469.57 for cement ponds with mud bottom and Rs 8,821.27 for mud ponds. Benefit-Cost Ratio for cement ponds, cement mud bottom ponds and mud ponds was 1.06, 1.17 and 1.58 respectively. Thus, Jhora fisheries was economically feasible and profitable venture.

Growth, instability and production analysis of oilseeds in India

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The study was conducted based on secondary data collected for the period covered span of 30 years from 1989-90 to 2018-19. The study includes all nine oilseed crops. The study concluded that more area, production and productivity of oilseeds were contributed by kharif season crops than compared to rabi season in the country. The variation in yield of oilseeds was mostly observed in kharif crops than compared to rabi crops. The sunflower, safflower, nigerseed and castor seed showed more fluctuation in area, whereas in production all crops showed mild variation except sesamum crop and in productivity highest variation was seen in soyabean, safflower and groundnut crops.

Support vector machine and its application in agricultural economics research

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The classification of agricultural data is an important application of information technology in agriculture. Support vector machine (SVM) is a powerful state-of-the-art classifier and has been applied in many fields. In this paper, SVM is introduced to classify the agricultural data for improving the classification performance and forecast the data. In order to understand SVM, a study was conducted on credit cards of defaulter and non-defaulters using 12391 observations and 31 variables over 15 days. To measure the accuracy, the SVM model was compared with other classification techniques such as Decision Tree (DT), Random Forest (RF), and Logistic Regression (LR). The results highlighted that SVM (linear) has greater accuracy as comparison to other methods. SVM is an alternative, promising technique compared to time series forecasting. Another study on forecasting of oilseed production in India was done for the period from 1949 to 2017. The SVM model was compared with ARIMA model. The results highlighted that SVM model is better in comparison to ARIMA considering the mean absolute percentage error.

Growth and investments in Indian agriculture: Assessment of recent trends, breaks, and linkages

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This paper reviews the recent trends in agricultural investments and output and tries to find structural breaks in the trends over the period of 1960-2016. Comparing the growth performance of various sub-periods based on breakpoints in the series the study finds that the recent agricultural stagnation spawns from a low capital formation in Indian agriculture. This has been further strengthened by the regression results where both public and private investments along with fertilizer consumption, HYV seeds, terms of trade, and weather pattern significantly affect the agricultural output (in terms of GDPA). We also find that there is an overall declining trend of efficiency of capital use in Indian agriculture. Given the efficiency and under the assumption of ceteris paribus, we find the warranted growth rate in private investment is around 5% and in public investment is around 2% to achieve the 4% growth target in agricultural output. Therefore, the policy implication of the study calls for an immediate arrest of the declining trend of public investment in order to stimulate more private investment. This may break the shackles of growth stagnation in Indian agriculture.

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