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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:

$$[LnY_{cons} - LnY_{conv}] = [Ln\beta_0 - Ln\alpha_0] + [LnX_{1conv}(\beta_1-\alpha_1) + LnX_{2conv}(\beta_2-\alpha_2) + LnX_{3conv}(\beta_3-\alpha_3) + LnX_{4conv}(\beta_4-\alpha_4) + LnX_{5conv}(\beta_5-\alpha_5) + LnX_{6conv}(\beta_6-\alpha_6) + LnX_{7conv}(\beta_7-\alpha_7) + LnX_{8conv}(\beta_8-\alpha_8)] + [\beta_1 Ln(X_{1cons}/X_{1conv}) + \beta_2 ln(X_{2cons}/X_{2conv}) + \beta_3 Ln(X_{3cons}/X_{3conv}) + \beta_4 Ln(X_{4cons}/X_{4conv}) + \beta_5 Ln(X_{5cons}/X_{5conv}) + \beta_6 Ln(X_{6cons}/X_{6conv})] + \beta_7 Ln(X_{7cons}/X_{7conv})] + \beta_8 Ln(X_{8cons}/X_{8conv})] + [u_{cons} - u_{conv}] \quad \dots(5)$$

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.

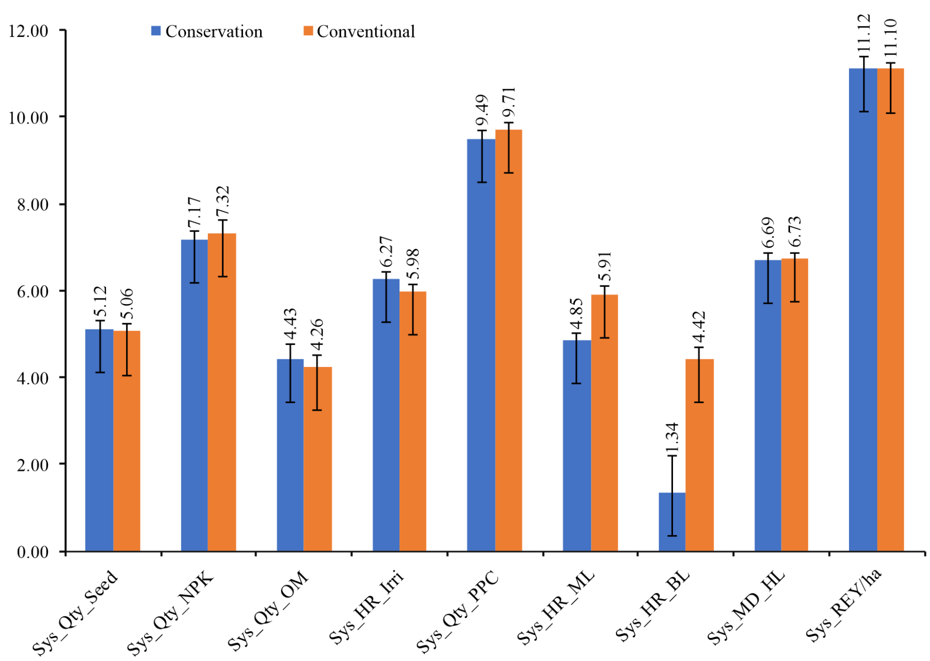
Comparative economics of conservation and conventional agriculture

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.

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