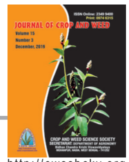
Journal of Crop and Weed, 18(3): 223-237 (2022)

ISSN- O : 2349 9400 ; P : 0974 6315



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An economic impact of conservation agriculture on small and marginal farms in West Bengal, India: An assessment with DID method

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Received : 27.04.2022 ; Revised : 25.06.2022 ; Accepted : 30.06.2022

DOI : https://doi.org/10.22271/09746315.2022.v18.i3.1640

ABSTRACT

Prototype agriculture is facing several socio-economic and environmental challenges regarding sustainable livelihood and food security, particularly for marginal and small households in India. Soil erosion, nutrient mining, dwindling water tables and declining biodiversity are currently the most serious problems in the long run agricultural sustainability in the country. However, the motive of this research is to determine the financial impact of conservation agriculture in West Bengal temporally as an alternative solution to those issues. The study compares the overall economic change of system productivity and returns cost ratio under conservation agricultural farms with respect to conventional farming situations over two years using the Differences in Difference (DID) method of estimation. The results depicted that the changes in the SREY of conservation agriculture over conventional farms have increased from 4944.88 kg ha^{-1} in 2019-20 to 8479.95 kg ha^{-1} in 2020-21 with an overall gain of 3535.07 kg ha^{-1} over two years. Over the two-year study period, the overall change in system net return and system B: C ratio for conservation agriculture compared to conventional farms was increased to Rs.1,09,105/-and Rs. 0.38 per hectare. Barring organic manure use, conservation agriculture has utilized less tillage, less inputs, less mechanization and less manpower. Finally, the estimated change in system productivity over two years was recorded 69.13% gain in conservation farms with respect to conventional cultivation practices featuring a successful implementation of conservation agriculture in the state.

Keywords**:** Conservation agriculture, DID, economic impact

In today's world, prototype agriculture faces various obstacles, posing a great threat to food and nutritional security. Intensive agriculture and external inputs are being excessively used, resulting into soil, water, and genetic resource degradation, as well as negatively influencing agricultural production and productivity. Natural resource deterioration poses a severe challenge to satisfying future demand for food, feed, fodder and fibre. Soil erosion, nutrient mining, diminishing water tables, degrading biodiversity, and rising environmental pollution are the key challenges impacting the poor and underprivileged's food security and livelihood chances. Soil degradation caused by erosion and compaction processes is becoming a burning issue under conventional agriculture nowadays. The main reasons responsible for this are soil organic matter loss, soil structural degradation, water and wind erosion, reduced water infiltration rates, surface sealing and crusting, soil compaction, insufficient return of organic material, mono-cropping in most farming situations across the region, declining crop factor productivity and the limited potential of ZT and its effect on soil carbon sequestration and climate change (Hobbs and Govaerts 2010, Chatterjee *et al.,* 2015; Veloso *et al.*, 2020; Mondal *et al.*, 2020; Nandan *et al.*, 2019; Gonzalez-Sanchez *et al.*, 2019; Njaimwe *et al.*, 2018; Zhang *et al.,* 2015; Sapkota *et al.,* 2017; Jat *et al.*, 2018; Roy *et al.,* 2022; Dolan *et al.*, 2006; Luo *et al.*, 2010; Piccoli *et al.*, 2016; Baker *et al.,* 2007; Powlson *et al.*, 2014; Corbeels *et al.*, 2020).

Shifting in farming practices is highly appreciated by removing unsustainable parts of conventional agriculture (ploughing / tilling the soil, removing all organic material, monoculture) in order to increase future productivity (Bhan and Behera, 2014). The concept of conservation agriculture has arisen in response to global concerns about agriculture's sustainability. It has steadily grown to cover around 8% of the world's arable land (124.8 M ha) (FAO, 2012). This agricultural production system is resource-conserving, also able to achieve high yields and production intensification while preserving the natural resource (Abrol and Sangar, 2006). However, scientists have entrusted that this farming system can guarantee higher yields with assured food security and environmental protection in the long run (Patzek, 2008; Govaerts *et al.*, 2009; Verhulst *et al.,* 2010). Traditional agriculture, which relies heavily on intensive tillage and is highly mechanised, has been blamed for soil erosion, surface and subsurface water contamination and increased water usage (Wolff and Stein, 1998).

However, CA-based systems have primarily been adopted on large commercially active farms by smallholder farmers in Brazil, Ghana, Zambia, Zimbabwe, and India's Indo-Gangetic plains (Ekboir *et*

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How to cite : Chatterjee, S., Hasan, M. and Chakraborty, R. 2022. An economic impact of conservation agriculture on small and marginal farms in West Bengal, India: An assessment with DID method. J. *Crop and Weed*, **18** (3): 223-237.

al., 2002; Haggblade and Tembo, 2003; Bolliger *et al*., 2006; Wall, 2007; Erenstein and Laxmi, 2008). Several research initiatives have looked at the possible impact of conservation agriculture in both a temporal and spatial manner, using a variety of methodologies. Conservation agriculture is generally a "win-win" situation for both farmers and the environment. Conservation agriculture is spreading to farmers with zero-tillage farming which covers the soil with crop residue, conserves water, progressively enhances soil organic matter, and controls weeds while lowering mechanical, fuel, and time expenses associated with tilling, allowing the soil to breathe promotes water infiltration, retains soil moisture, reduces topsoil erosion, etc.

OBJECTIVES

In light of the foregoing, the current study aims to compare the total change in system productivity of the conservation farming compared to the conventional farming over two time periods (2019-20 and 2020-21). The difference in differences method of computation was used to assess the predicted improvement in output over two years to compare to the conservation farms.

MATERIALS AND METHODS

Conceptual framework

Difference in differences (DID or DD) is a statistical technique used in econometrics and quantitative social science research that attempts to mimic an experimental research design using observational study data by examining the differential effect of a treatment on a 'treatment group' versus a 'control group' in a natural experiment. It compares the average change over time in the outcome variable for the treatment group to the average change over time in the outcome variable for the control group to calculate the effect of a treatment (i.e., an explanatory variable or an independent variable) on an outcome (i.e., a response variable or dependent variable). As a result, the proposed hypotheses for this investigation would be structured as a 22 matrix for the t_1 and t_2 time frames:

Hypotheses	H_0	H_1
t_1	$H_0\, t_1$**:** There are no significant differences between the treatment and control groups	$H_1\, t_1$**:** Treatment and control group differences
t_2	$H_0\, t_2$**:** There are no significant changes between the treatment and control groups.	$H_1\, t_2$**:** Treatment and control group differences

Note: t_1: 2019-20 t_2: 2020-21 Treatment group: Conservation agriculture farms Control group: Conventional farms

Data description, stratification and sampling technique

A primary survey of 100 farm households was used to conduct the research. This research was conducted in the reference years of 2019-20 and 2020-21. The study's survey area was made up of three blocks from the Nadia District of West Bengal: Haringhata, Chakdaha, and Krishnanagar-I. This survey location was chosen because it is located in India's lower gangetic alluvial plains, where farmers often practice conservation agriculture. However, in the study sites, summary descriptive data on the socio-economic status of a hundred sample farm households (fifty from each of the farming situations) are provided (Table 1). 20 households from Haringhata block , 15 households from Chakdaha block, and 15 households from Krishnanagar-I block for each of the farming situations were based on purposive sampling. The average age of the farm family's head was roughly 50 years old, with more than thirty years of farming experience and a Class VIII educational level. All belonged to Hindu religion with scheduled caste and tribes. All of the farms were tiny and marginal, with an average operating holding of 1.01 hectares for all of them. Conservation farms covered 1.16 hectares, whereas conventional farms covered 0.86 hectares (Chatterjee *et al.,* 2020). However, average non-farm income of the family has been recorded Rs. 46,515/- where conservation farms were slightly better than the conventional ones. The average farm-present family's assets, including land have been increased to Rs. 59, 19, 295/-. Crop along with livestock has been identified as the most important farming system in this region, with each farm family owning at least two milch cows and an average return of Rs. 7,77,835/- per farm, whereas conservation farms yielded a higher return (20.91 per cent) than conventional farm households. The average consumption expenditure per family was Rs. 2, 48,290/-. For the hundred farm households in this region, fifty each having conservation and conventional farming situations, the required data set on socio-economic parameters as well as cost and quantity of various inputs used under these two farming situations for both periods have been collected, gathered, and compiled.

The study has considered four major crops grown under two farming situations for both the years as winter rice, summer rice, jute, and dolichos bean in the cropping season (Table 2) on which the system rice equivalent productivity and system input use for each household has been computed subsequently.

Empirical strategy

$Y_{it} = \alpha_{s(i)} + \lambda_t + \delta I + \varepsilon_{it}$

Where, Y_{it} is denoted as the dependent variable (SREY[1]) for individual *i* (farming situations) overtime *t* (t_1 = 2019-20 and t_2 = 2020-21), ***i*** belonged to the groups ***(i)*** (i.e. either the conservation farming situation or the conventional farming situation) and *I* is denoted as the dummy variable which is 1 for conservation farming situation when the event is true and 0 for conventional farming situation. In the plot of time versus ¾ by group, α_s is denoted as the vertical intercept for the graph for ***s*** (conservation or conventional farming situation), and λ_t is denoted as the time trend shared by both groups according to the parallel trend assumption. δ is denoted as the effect on conservation farming and ε_{it} is denoted as the residual term.

n_s = Number of respondents in group (conservation or conventional)

$$\bar{y}_{st} = \frac{1}{n_s}\sum_{i=1}^{n} y_{it} I(s(i) = s)$$

$$\bar{\alpha}_s = \frac{1}{n_s}\sum_{i=1}^{n} y_s(i) I(s(i) = s) = \alpha_s,$$

$$\bar{\lambda}_{st} = \frac{1}{n_s}\sum_{i=1}^{n} y_t I(s(i) = s) = \lambda_t,$$

$$D_{st} = \frac{1}{n_s}\sum_{i=1}^{n} I(s(i) = \text{treatment, t in after period}), \quad I(s(i) = s) = I(s = \text{treatment, t in after period})$$

$$\bar{\epsilon}_{st} = \frac{1}{n_s}\sum_{i=1}^{n} \epsilon_{it} I(s(i) = s),$$

For simplicity, consider that ***s*** =1, 2 (1 for conservation and 2 for conventional farming situation) and ***t*** =1,2 (1 for 2019-20 and 2 for 2020-21). Note that D_{st} only encodes how the groups and the periods are labeled.

$$(\bar{y}_{11} - \bar{y}_{12}) - (\bar{y}_{21} - \bar{y}_{22})$$

$$= [(\alpha_1 + \lambda_1 + \delta D_{11} + \bar{\epsilon}_{11}) - (\alpha_1 + \lambda_2 + \delta D_{12} + \bar{\epsilon}_{12})] - [(\alpha_2 + \lambda_1 + \delta D_{21} + \bar{\epsilon}_{21}) - (\alpha_2 + \lambda_2 + \delta D_{22} + \bar{\epsilon}_{22})]$$

$$= \delta(D_{11} - D_{12}) + \delta(D_{22} - D_{21}) + \bar{\epsilon}_{11} - \bar{\epsilon}_{12} + \bar{\epsilon}_{22} - \bar{\epsilon}_{21}$$

As a result of the rigorous exogeneity assumption,

$$\mathbf{E}[(\bar{y}_{11} - \bar{y}_{12}) - (\bar{y}_{21} - \bar{y}_{22})] = \delta(D_{11} - D_{12}) + \delta(D_{22} - D_{21})$$

Assume that $s = 2$ is the treatment group and $t = 2$ is the after period without losing generality then, $D_{22} = 1$ and $D_{11} = D_{12} = D_{21} = 0$, when the DID estimator is given.

$\hat{\delta} = (\bar{y}_{11} - \bar{y}_{12}) - (\bar{y}_{21} - \bar{y}_{22}), D_{st}$ is used to indicate the treatment effect. This estimator is a coefficient in an ordinary least squares regression in the example below. The model described in this section is over-parameterized; to correct this, one of the dummy variable coefficients can be set to zero, for example, $\alpha_1 = 0$ can be set.

Implementation

The DID technique can be implemented by using the table below, with the DID estimator in the lower right cell.

y_{st}	*s = 1*	*s =2*	**Difference**
t = 1	$\bar{y}_{11}$	$\bar{y}_{12}$	$\bar{y}_{11} - \bar{y}_{12}$
t =2	$\bar{y}_{21}$	$\bar{y}_{22}$	$\bar{y}_{21} - \bar{y}_{22}$
Change	$\bar{y}_{11} - \bar{y}_{21}$	$\bar{y}_{12} - \bar{y}_{22}$	$(\bar{y}_{21} - \bar{y}_{22}) - (\bar{y}_{11} - \bar{y}_{12})$

Note: where

$s = 1$ conservation farming situation,

$s = 2$ conventional farming situations

$t = 1$ = 2019-20 $t = 2$ = 2020-21

$\bar{y}_{11}$ = *SREY of 1st year in conservation farming*

$\bar{y}_{12}$ = *SREY of 1st year in conventional farming*

$\bar{y}_{21}$ = *SREY of 2nd year in conservation farming and*

$\bar{y}_{22}$ = *SREY of 2nd year in conventional farming*

Regression analysis

Regression analysis is a reliable method of identifying variables having an impact on the farming situation. The process of performing a regression allows to confidently determine which factors matter most, which factors can be ignored, and how these factors influence each other.

Here, the OLS model was considered,

$$y = \beta_0 + \beta_1 T + \beta_2 S + \beta_3 (T.S) + \varepsilon$$

Where, T is denoted as a dummy variable for the period, equal to 1 when $t = 2$ and S is denoted as a dummy variable for group membership, equal to 1 when $s = 2$. The composite variable ($T. S$) is denoted as a dummy variable indicating, when ($T = S = 1$).

$$\hat{\beta}_0 = \hat{E}(y|T = 0, S = 0)$$

$$\hat{\beta}_1 = \hat{E}(y|T = 1, S = 0) - \hat{E}(y|T = 0, S = 0)$$

$$\hat{\beta}_2 = \hat{E}(y|T = 0, S = 1) - \hat{E}(y|T = 0, S = 0)$$

$$\hat{\beta}_3 = [\hat{E}(y|T = 1, S = 1) - \hat{E}(y|T = 0, S = 1)] - [\hat{E}(y|T = 1, S = 0) - \hat{E}(y|T = 0, S = 0)]$$

Where, $\hat{E}(\ldots|\ldots)$ is denoted as the conditional averages computed on the sample; for example, ***T= 1*** denotes the after period and ***S= 0*** is the control group.

$$\hat{E}(y|T = 1, S = 0) = \hat{E}(y|\text{after period, control})$$

$$= \frac{\hat{E}(yI\ (\text{after period, control}))}{\hat{P}(\text{after period, control})}$$

$$= \frac{\sum_{i=1}^{n}(y_{i,after} I(\text{iin control}))}{n_{control}}$$

$$= \bar{y}_{\text{control, after}}$$

$$= \bar{y}_{12}$$

For other values of ***T*** and ***S***, which is equivalent to, $\hat{\beta}_3 = (y_{11} - y_{21}) - (y_{12} - y_{22})$

F test

To examine the differences between conventional and conservation farmers, overall regression analysis with the F test has been used. If there are n data points from which parameters need to be estimated for both models, then the F statistic can be calculated as follows:

$$F = \frac{(RSS1 - RSS2)/(p2 - p1)}{(RSS2/n - p2)}$$

Where, RSS_i is denoted as the residual sum of squares of model i. RSS_i should be replaced with χ^2 (the weighted sum of squared residuals) when the regression model is being calculated with weights. According to the null hypothesis, if model 2 does not provide a significantly better fit than model 1 then F will have a 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 considered as a Wald test.

RESULTS AND DISCUSSION

The difference between CA and conventional practices with respect to average crop productivity and residual yield from various crop enterprises per hectare of sample farm households is highlighted in Table 3. The conservation farm-families usually incorporate crop residues in the field and cover crops to conserve residual moisture in soil. In the contrary to this, farm families who are practicing conventional way of farming, feed

Table 1: Descriptive statistics of baseline socio-economic status for the sample farm households under conservation and conventional farming situation in Nadia district of *West Bengal*

Parameters	Units	Conservation agriculture households		Conventional agriculture households		Total number of households under conservation and conventional farming	
		50 Farm households		50 Farm households		100 Farm households	
		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	Rs.annum^{-1}	48,930/-	82,950/-	44,100/-	83,630/-	46,515/-	82,260/-
Total valuation of current assets (land, pond, dwelling house and farm machineries)	Rs.annum^{-1}	68,57,827/-	47,04,890/-	49,80,760/-	16,94,290/-	59,19,295/-	36,17,475/-
Gross return from crops	Rs.annum^{-1}	8,26,928/-	1,73,733/-	6,83,673/-	1,15,703/-	7,51897/-	1,65,260/-
Gross return from animals	Rs.annum^{-1}	28,270/-	26,290/-	23,600/-	21,690/-	25,938/-	23,264/-
Total consumption expenditure	Rs.annum^{-1}	2,54,657/-	2,09,670/-	2,41,923/-	2,26,995/-	2,48,290/-	2,15,780/-

Source: Field Survey

Standard deviation is denoted as SD

Code used for, Sex/Gender: If, Male then 1; If, Female then 2

In case of Education: If, Illiterate then1; Up to primary- 2; High school- 3; Graduate and above- 4

In case of Religion: If, Hindu then 1; If, Muslim then 2

In case of Caste: If, Scheduled Caste then 1; If, Scheduled Tribe then 2; If, Other backward class then 3; If, General then 4; If, something else then 5

Table 2: Various crops which have been identified among sample farm households

Items	
Crops which are being grown under conservation and conventional farming	Summer rice, Winter rice, Dolichos bean, Jute

Table 3: Average crop productivity (kg ha^{-1}) and residual yield (kg ha^{-1}) from various crops cultivated by sample farms following conservation and conventional farming in Nadia district of West Bengal

Types of Farming	Winter rice			Dolichos bean			Summer rice			Jute		
	2019-20	2020-21	% Change	2019-20	2020-21	% Change	2019-20	2020-21	% Change	2019-20	2020-21	% Change
Conservation	3829	4271	10.35	26194	26561	1.38	6855	5722	-19.80	2928	2467	-18.69
	(5513)	(6067)	(9.13)	(39290)	(36818)	(-6.71)	(9597)	(8011)	(-19.80)	(14639)	(12430)	(-17.77)
Conventional	4498	4458	-0.90	40907	25135	-62.75	5602	5355	-4.61	2615	2885	9.36
	(7663)	(6326)	(-21.13)	(61361)	(35260)	(-74.02)	(7811)	(7497)	(-4.19)	(13077)	(14423)	(9.33)
Pooled	**4163**	**4364**	**4.61**	**33550**	**25848**	**-29.80**	**6229**	**5539**	**-12.46**	**2772**	**2676**	**-3.59**
	(6588)	**(6196)**	**(-6.33)**	**(50326)**	**(36039)**	**(-39.64)**	**(8704)**	**(7754)**	**(-12.25)**	**(13858)**	**(13427)**	**(-3.21)**

Note: Figure in the parentheses represents respective crop residue yield ($kgha^{-1}$)
Source: Field Survey

Table 4: Comparative differences in differences for Economics of Geometric Mean value of two year (Y11-Y12) in 1st year 2019-20 and (Y21-Y22) in 2nd year 2020-21

Type of Farming	Sys_REY kg ha-1	System_GR (Rs ha-1)	System_COC (Rs ha-1)	System_NR (Rs ha-1)	Return per rupee of investment (B:C)
Conservation ($\overline{y}_{11}$)	61587.32	810225	317755	482261	2.55
Conventional ($\overline{y}_{12}$)	56642.44	806698	349451	445288	2.31
$\overline{y}_{11}$ - $\overline{y}_{12}$	4944.88	3527	-31696	36973	0.24
1stYear Relative change (%)	8.73	0.44	-9.07	8.30	10.46
Conservation ($\overline{y}_{21}$)	52251.01	826928	243192	583736	3.40
Conventional ($\overline{y}_{22}$)	43771.06	683673	246015	437658	2.78
$\overline{y}_{21}$ - $\overline{y}_{22}$	8479.95	143255	-2823	146078	0.62
2ndYear Relative change (%)	19.37	20.95	-1.14	25.02	22.30
($\overline{y}_{21}$-$\overline{y}_{22}$)-($\overline{y}_{11}$ - $\overline{y}_{12}$)	3535.07	139728	28873	109105	0.38

Source: Authors' estimates

Note:

$\overline{y}_{11}$ = SREY of 1st year in conservation farming
$\overline{y}_{12}$ = SREY of 2nd year in conservation farming
$\overline{y}_{21}$ = SREY of 1st year in conventional farming and
$\overline{y}_{22}$= SREY of 2nd year in conventional farming
Sys_REY/ha=System Rice equivalent Yield per Hectare
System_GR/ha = System Gross Return per Hectare
System_COC/ha= System Total Cost per Hectare
System_NR/ha = System Net Return per Hectare

Crop	Price (Rs./Kg)	
	2019-20	2020-21
1. Winter Rice	11.66	14.5
2. Dolichos bean	20	20
3. Summer Rice	16.66	11.5
4. Jute	32	40

Table 5: Regression coefficients of sample conservation and conventional farms under study

Particulars	Parameters	2019-20			2020-21		
		Conservation farm households	Conventional farm households	Pooled	Conservation farm households	Conventional farm households	Pooled
No. of farm households	**N**	**50**	**50**	**100**	**50**	**50**	100
Intercept	a	3.98**	10.66*	6.38**	-2.95**	0.12**	-2.15**
System quantity seed (kgha^{-1})	X_1	-0.35	-0.44	-0.23	0.64	-1.52	0.10
System quantity NPK (kgha^{-1})	X_2	-0.04	-0.27	-0.05	1.22**	0.96	0.97**
System quantity organic manure(qha^{-1})	X_3	-0.30	-0.02	-0.13	-0.08	0.08	-0.18
System irrigation (hour ha^{-1})	X_4	0.42	-0.11	0.14	0.01	0.46	0.10
System quantity PPC (g/ml per l ha^{-1})	X_5	-0.13	-0.04	0.03	0.11	0.10	0.21
System machine labour (hourha^{-1})	X_6	-0.06	0.03	-0.28	-0.12	-0.48	0.07
System bullock labour (pair hourha^{-1})	X_7	-0.03	-0.07	-0.04	0.00	0.00	0.00
System human labour (mandays ha^{-1})	X_8	1.41**	0.85	1.11**	0.34	1.43	0.57
Dummy variable for pooled analysis		-	-	-0.27	-	-	0.31
Coefficient of multiple determination	R^2	0.93	0.63	0.71	0.97	0.79	0.81
Adjusted R square	R^2	0.88	0.36	0.62	0.86	0.58	0.73
F value ($p = 0.05$)	F	18.99	2.31	8.02	49.88	6.28	16.65
F critical ($p = 0.05$)	F	2.17	2.17	1.99	2.17	2.17	1.99

Note: * ** significant at $p = 0.05$ and $p = 0.01$ respectively
Source: Authors' estimates

Table 6: Regression equation of predicted Y_i for conservation and conventional Farms

Year	Types of farming	Regression equation
2019-20	Conservation	$\ln(Y_{11}) = \ln(3.98) - 0.35(\ln seed) - 0.04(\ln NPK) - 0.30(\ln OM) + 0.42(\ln Irri) - 0.13(\ln PPC) - 0.06(\ln ML) - 0.03(\ln BL) + 1.41(\ln HL)$
	Conventional	$\ln(Y_{12}) = \ln(10.66) - 0.44(\ln seed) - 0.27(\ln NPK) - 0.02(\ln OM) - 0.11(\ln Irri) - 0.04(\ln PPC) + 0.03(\ln ML) - 0.07(\ln BL) + 0.85(\ln HL)$
	Pooled	$\ln(Y_1) = \ln(6.38) - 0.27(\ln Dummy) - 0.23(\ln seed) - 0.05(\ln NPK) - 0.13(\ln OM) + 0.14(\ln Irri) + 0.03(\ln PPC) - 0.28(\ln ML) - 0.04(\ln BL) + 1.11(\ln HL)$
2020-21	Conservation	$\ln(Y_{21}) = \ln(-2.95) + 0.64(\ln seed) + 1.22(\ln NPK) - 0.08(\ln OM) + 0.01(\ln Irri) + 0.11(\ln PPC) - 0.12(\ln ML) - 0.00(\ln BL) + 0.34(\ln HL)$
	Conventional	$\ln(Y_{22}) = \ln(0.12) - 1.52(\ln seed) + 0.96(\ln NPK) + 0.08(\ln OM) + 0.46(\ln Irri) + 0.10(\ln PPC) - 0.48(\ln ML) - 0.00(\ln BL) + 1.43(\ln HL)$
	Pooled	$\ln(Y_2) = \ln(-2.15) + 0.31(\ln Dummy) + 0.10(\ln seed) + 0.97(\ln NPK) - 0.18(\ln OM) + 0.10(\ln Irri) + 0.21(\ln PPC) + 0.07(\ln ML) + 0.0(\ln BL) + 0.57(\ln HL)$

Note :

Y_{11} = Conservation Farming Situation in 1st Year (2018-19)
Y_{12} = Conventional Farming Situation in 1st Year (2018-19)
Y_1 = Pooled Farming Situation in First Year (2018-19)
Y_{21} = Conservation Farming Situation in 2nd Year (2019-20)
Y_{22} = Conventional Farming Situation in 2nd Year (2019-20)
Y_2 = Pooled Farming Situation in 2nd Year (2019-20)

Table 7: Comparative differences in differences of Mean value of Two Year(Y11-Y12) in 1st year 2019-20 and (Y21-Y22) in 2nd year 2020-21

Type of Farming	Sys_REY Actual (kg)(Yi)	Sys_Qty_ Seed (kg)	Sys_Qty_ NPK (kg-nutrient)	Sys_Qty_ OM(qtl)	Sys_HR_ Irri(hr)	Sys_Qty_ PPC (gm/ml/lit)	Sys_ML (hr)	Sys_BL (hr)	Sys_HL (Man-days)	Sys_REY Predicted (kg)(	Error
Conservation ($\bar{y}_{11}$)	61587	149.82	1116.55	88.55	500.32	11050.84	113.61	10.84	692.67	61518.35	68.97
Conventional ($\bar{y}_{12}$)	56642	128.65	1359.64	60.98	344.81	13206.52	300.23	55.30	681.39	56437.52	204.92
$\bar{y}_{11}$ - $\bar{y}_{12}$	4945	21.17	-243.09	27.57	155.52	-2155.68	-186.63	-44.47	11.28	5080.83	-135.96
1st Year Relative change (%)	8.73	16.45	-17.88	45.22	45.10	-16.32	-62.16	-80.41	1.66	9.00	-66.35
Conservation ($\bar{y}_{21}$)	52251	114.28	1003.32	74.12	364.31	5203.93	37.83	1.00	567.33	52231.80	19.21
Conventional ($\bar{y}_{22}$)	43771	123.64	1011.14	38.77	291.20	6024.29	48.15	1.00	600.54	43638.37	132.69
$\bar{y}_{21}$ - $\bar{y}_{22}$	8480	-9.36	-7.82	35.35	73.10	-820.36	-10.32	0.00	-33.21	8593.43	-113.48
2nd Year Relative change (%)	19.37	-7.57	-0.77	91.17	25.10	-13.62	-21.43	0	-5.53	19.69	-85.52
($\bar{y}_{21}$-$\bar{y}_{22}$)-($\bar{y}_{11}$-$\bar{y}_{12}$)	3535	-30.52	235.27	7.78	-82.41	1335.32	176.31	44.47	-44.50	3512.60	22.47

Source: Authors' estimates

Note:

$\bar{y}_{11}$ is denoted as SREY of 1st year in conservation farming
$\bar{y}_{12}$ is denoted as SREY of 2nd year in conservation farming
$\bar{y}_{21}$ is denoted as SREY of 1st year in conventional farming and
$\bar{y}_{22}$ is denoted as SREY of 2nd year in conventional farming
Sys_REY Actual is denoted as Actual System Rice Equivalent Yield
Sys_Qty_Seed is denoted as System Quantity of Seed
Sys_Qty_NPK is denoted as System Quantity of Nitrogen, Phosphorus, potassium.
Sys_Qty_OM is denoted as System Quantity of Organic Matter
Sys_HR_Irri is denoted as System Quantity of Irrigation
Sys_Qty_PPC is denoted as System Quantity of Production Chemical
Sys_ML is denoted as System Quantity of Machine Labour in Hour
Sys_BL is denoted as System Quantity of Bullock Labour in Hour
Sys_HL is denoted as System Quantity of Human Labour in Man-Days
Sys_REY Predicted is denoted as Predicted System Rice Equivalent Yield

the crop residues to their livestocks and also sell the surplus production. In this way, they completely avoid the incorporation of crop debris into the soil. However, data in Table 3 reveals that *kharif* paddy and dolichos bean have been witnessed to provide better productivity in 2019-20 as compared to 2018-19 (10.35% and 1.38% respectively) but failed to regain yield level for *boro* paddy and jute in the current year. As these two crops are supposed to be heavy feeder, which requires intensive cultivation practices and input management, won't be congenial for the conservation technology with no tillage and minimum level of input use. Thus, in natural sense, *boro* paddy and jute yielded less in 2019-20. However, the crop productivity of jute has been enhanced for conventional farming situation in 2019-20, owing to better management practices and better use of inputs.

Comparative economics of conservation and conventional farms over two periods

A comparative analysis on economic impact between these two farming systems in our sample area over two years of study was highlighted in Table 4, where there was 6.35% rise in SREY for conservation agriculture over conventional farming in 2019-20, which has gone up to 17.78% relative change in 2020-21. The relative change in system gross return has been increased a mammoth for conservation agriculture (20.95%) for the year 2020-21 as compared to a minute change in the first year (0.44%). This indicates a significantly positive impact of conservation agriculture over the traditional farming situation as the time progresses. However, the cost of cultivation was much low for the conservation agriculture (-9.07%) in first year (2019-20) while it has gone up to more or less equal to the traditional farming for the second year (2020-21) (-1.14%). As a result, the overall net return and return per rupee of investment for conservation agriculture as compared to traditional farming has gone up from 8.30% in 2019-20 to 25.02% in 2020-21 and 10.46% in 2019-20 to 22.30% in 2020-21, respectively.

Overall, the comparison of economics of conservation agriculture as compared to the conventional farming situation between two-time frames (2019-20 and 2020-21) have showed 4081 kg ha^{-1} more gain in SREY, Rs. 1, 39,728/- more system Gross return, Rs. 28,873/- more cost of cultivation, Rs. 1,09,105/- more net return and Rs. 0.38/- more gain per rupee of investment using double differences method of computation.

Regression estimates of conservation and conventional farms over two years

Table 5 and 6 represent the regression estimates between SREY and various system input use for conservation and conventional farms over two years of study. However, pooled regression analysis including dummy variable was performed for both the years in order to assure the significant change between two farming situations. F-statistics in both the years were appeared to be significantly high over critical value which ensures the acceptance of alternative hypotheses in both the time frames. The fitted regression equation for fifty conservation farm households for both the years (2019-20 and 2020-21) were $\ln (y_{11}) = \ln (3.98) – 0.35 (\ln seed) – 0.04 (\ln npk) – 0.30 (\ln om) + 0.42 (\ln irri) – 0.13 (\ln ppc) – 0.06(\ln ml) – 0.03(\ln bl) + 1.41(\ln hl)$ and $\ln (y_{21}) = \ln (-2.95) + 0.64 (\ln seed) +1.22 (\ln npk) – 0.08 (\ln om) + 0.01 (\ln irri) + 0.11 (\ln ppc) – 0.12 (\ln ml) – 0.00 (\ln bl) + 0.34 (\ln hl)$ where, irrigation and human labour were the positive indicators towards the system productivity under conservation agriculture while other factors had negative impact on system yield. The intercept coefficient (3.98) is positive indicating some sorts of positive impact of conservation agriculture regarding inherent fertility status of the soil in 2019-20 while it was highlighted negative (-2.95) in 2020-21 indicating some sorts of negative impact of conservation agriculture regarding the state of technology adoption. Seed, quantity NPK applied, irrigation, plant protection chemicals and human labour were the positive indicators towards the system productivity under conservation agriculture while other factors were of negative impact on system yield. The intercept appeared to be very high for the conventional farming situation (10.66) in 2019-20 featuring better fertility due to better tillage, intercultural operation and more mechanization.

Economic impact of conservation agriculture over two years

Table 7 has revealed the final differences in difference of conservation and conventional farming over two successive years of experimentation. However, with a closer look on the entire table, it was observed that the actual gain in conservation agriculture over two years of operation was recorded as 3535 kg ha^{-1} in terms of SREY while the predicted change was registered as 3512 kg ha^{-1}. There was a spectacular decrease in human labour utilization (-394.41%) in conservation agriculture after making two successive differences over two years of operations. Barring organic manure (28.20%), all the inputs have been registered lesser and lesser use in conservation agriculture over conventional farming in two successive years. The double differences method has evolved the successive differences of two farming situations between two points of time. It was revealed that the second year has featured much gaining in SREY as compared to first year as extent of technology been adopted better in the second year.

With lesser use of inputs and lesser tillage, conservation agriculture has shown a mammoth gain in two successive years of experimentation in this region which can be widely promoted and executed district-wise and region-wise allover West Bengal where there are constraints of resource use.

Over the two years of observation, the current study has tried to find out the beneficial impact of conservation farming practice on marginal-small farm households in West Bengal. However, the concept, essence and techniques of CA have been brought from the successful initiation of resource conservation technology in Punjab and Haryana over the years where the average operational holding size of a farm exceeds 2.0 ha (Mahajan *et al.,* 2012). Thus, the farmers have their potential to bear higher risk and uncertainties in farming practices. Because of increased foodgrain productivity, increased farmer income, reduced poverty, and contributed significantly to national food security and self-sufficiency, today's agriculture is based on HYVs, high doses of chemical use, advanced plant protection technologies and intensive use of natural resources (Sidhu *et al.,* 2010, Sidhu and Bhullar, 2005; Joshi *et al*, 2004; *Government of India, 2006*, Chatterjee *et al.,* 2020). High growth rates in intensively cultivated farming systems have come at the expense of natural resource overexploitation, soil degradation, and increased global warming (Jat *et al.,* 2013). However, several constraints have been identified region-by-region to establish need-based sustainable cropping systems in India's indo-gangetic plains, such as nutrient imbalances/deficiencies and low nutrient use efficiency, high energy and labour demands, high greenhouse gas emissions, weed shift and resistance, and a drastic decline in ground water table, all of which threaten the rice-wheat system's long-term viability (Bhushan *et al.*, 2007; Gupta and Seth, 2007; Ladha *et al.*, 2009; Humphreys and Gaydon*,* 2015; Pathak *et al.*, 2011; Ram *et al.*, 2013; Das *et al.,* 2014). The superior performance of CA both spatially and temporally for the marginal and small farm households (in terms of economic impact status of the farmers) based on conservation agriculture, can be attributed to a variety of internal as well as external factors. Conservation agriculture requires the cultivation practices with reduced tillage, reduced mechanization and reduced manpower coupled with higher soil moisture retention, higher content of soil water and crop residue incorporation in the field (Paul *et al.,* 2014; Liu *et al.,* 2014; Choudhary and Suri*,* 2018). Less machine trafficking, higher organic matter, better nutrient dynamics and improved microbiological and soil physiochemical properties, ultimately result into enhanced crop growth (Ram *et al.,* 2013; Scopel *et al.,* 2013; Dass *et al.,* 2017). These basic changes brought an estimated change of 69.13% more system productivity for conservation agriculture with respect to conventional farming situation in West Bengal over the two years of study (2019-20 and 2020-21) with lesser mechanization (-94.47%), lesser man power (-394.41%) lesser NPK application (-96.78%) and lesser seed use (-144.21%). The outcomes support the reports related to such agricultural practices (Wang *et al.,* 2016) where CA can lead to improved input use, less system cost and finally contribute to the better crop productivity and farm economy as there was 29.05% more net savings per farm-family per annum under CA as compared to traditional farm households has been registered.It had also been observed that inorganic fertilizer and plant protection chemicals have featured less usage to crop while organic manure has got a greater usage under conservation agriculture system (7.78% positive change with respect to conventional farming over two years). This is a positive sign towards the sustainable goal and achievement with a clean and healthy eco-system in future agriculture that we all are looking for. On the contrary, results on disease pest management in CA highly contradicts previous studies (Kesavan and Malarvannan, 2010; Basch *et al.,* 2015; Craheix *et al.,* 2016) showing an increased pest-disease incidence in CA with undisturbed soil and crop residue incorporation) where conservation agriculture had registered 61.94% less use of PPC as compared to conventional farming over two years.

Conservation agriculture has produced less productivity for winter paddy, dolichos bean as compared to conventional farming in 2019-20 while summer paddy and jute exhibit more still there was a sound gain in system productivity and economic return in the year. However, the average crop productivity for winter paddy and dolichos bean has been increased to 10.35% and 1.38% respectively in 2020-21 under CA but failed to enhance further productivity for summer paddy and jute as these two crops are heavy feeder regarding NPK consumption, PPC and irrigation and need intensive cultivation practices and input management which would not be congenial for the conservation technology aspects with no tillage and minimum level of input use. However, the crop productivity of jute has been enhanced for conventional farming situation in 2019-20 as well owing to better management practices and better use of inputs. The change in technology has witnessed an overall 3535.0 kg ha^{-1} additional gain in system productivity under CA over conventional farming systems over the two years of study. However, CA is sustainable in the long run due to slow and steady acclimatization of soil fertility with minimum disturbance of soil. So, lack of yield benefits with an immediate effect of CA has been spotlighted by other researchers (Giller *et al.,* 2009; Gilbert, 2012). However, a gigantic temporal change in system productivity (71.49%) over traditional farming situation would contradict certain scientific beliefs about CA that crop yields were estimated to increase by 20–120% under CA (Kesavan and Malarvannan, 2010; Thierfelder and Wall, 2012; Basch *et al.*, 2015) in short run. It is the overall farming experience, knowledge and perception of the farmers as stressed out by Scopel *et al.* (2013) that would augment crop yield, soil evolutions and ecological equilibrium in long run.

Last but not the least, the return per rupee of investment for CA has gone up from 2.55 in 2019-20 to 3.40 in 2020-21 resulting in an overall 0.38-rupee (158.33%) gain over conventional farming situation as compared to two years of experimentation according to differences in difference method of computation. Hence, within a short run, with only two years of experimentation, CA exerts an immense impact to the livelihood situation of the sample farming households.

Recommendation for future research

The present study has tried to assess the temporal impact of CA in West Bengal over two years of experimentation using Double differences method (DID). However, the concept of resource conservation have not been adopted and flourished in every corner of the state, still it needs wide level of research and extension to establish the concept at farmer's level to sustain their overall livelihood in future.

CONCLUSION

Overall results of this study showed significant improvement in farm economy under conservation agriculture both temporally and spatially that combines crop-residue retention with minimum disturbances of soil, lesser input use and lesser mechanization in a cost-effective manner. This correlated well with the improved livelihood of farming community in this region over the year. Hence, the study believes the understanding and role of CA in alteration of the overall socio-economic livelihood status of the farmers.

ACKNOWLEDGEMENT

We are grateful to the Principal Investigator and all the team members of the project "Centre for Advanced Agricultural Science and Technology (CAAST) on "Conservation Agriculture", Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India for the whole hearted support and also Indian Council of Agricultural Research (ICAR), New Delhi as funding agency of the project for conducting the experiment on farmer's field in 2019-20 and 2020-21 as well.

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