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RESEARCH PAPER

Impact of Conservation Agriculture on Small and Marginal Farms in Telangana, India

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ABSTRACT

The preseant study attempts to assess and compare the economic impact of Conservation Agriculture (CA) over traditional farming (TF) in Telangana state of India, across 2019-20 and 2020-21. 100 sample farm households were taken into consideration from each farming situation through multi-stage sampling technique. The study evaluates productivity differences in the predominant paddy-maize cropping system due to technology intervention by employing Bisaliah decomposition and Difference in Differences (DiD) approach. The results reveal that the paddy-maize cropping system under CA has achieved a hike of 6.92% and 11.70% actual gain in system productivity over TF in these years, where the estimated change was statistically at par with the actual change. Farmers have enjoyed a 9.82% increase in returns under CA with curtailment of 11.17% cost, resulting in a significant increase in profit margin (39.42%) and return-cost ratio (23.97%) as compared to TF. Temporally, a productivity gap of 972.44 kg was observed in 2019-20 between CA and TF, which widened to 1432.34 kg in 2020-21, resulting in an overall system gain of 459.90 kg under CA. These hikes are attributed to technological intervention regarding changing method of cultivation practices, including minimum tillage, application of organic matter in soil with less NPK application and less workforce requirement in the field. Thus, CA needs to be recommended, which could protect the soil from degradation and losses.

HIGHLIGHTS

- Paddy-maize cropping system under CA has achieved a hike of 6.92% and 11.70% actual gain in system productivity over TF in two successive years (2019-20 and 2020-21).
- A productivity gap of 972.44 kg was observed in 2019-20 between CA and TF, which widened to 1432.34 kg in 2020-21.
- Farmers have enjoyed 9.82% increase in returns under CA with curtailment of 11.17% cost, resulting in increase in profit margin @ 39.42%.
- Technology has been disseminated in conservation farming with minimum tillage, more organic matter incorporation in soil with optimum utilization of human resources.

Keywords: Bisaliah, conservation, DiD, technology

Ensuring food security for the ever-growing population of India, alleviating poverty and maintaining agricultural sustainability has been a persistent challenge since independence. Although the Green Revolution in the 1960s

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marked a turning point by modernizing farming practices and boosting productivity, its long-term impact has waned in the past two decades. (Dam *et al*. 2024). Despite achieving record food grain production, practices like excessive tillage, indiscriminate machinery use, crop residue burning, and inadequate soil conservation continue to damage the environment, human health, and the livelihood of millions (Bhuvaneshwari *et al*. 2019). Indian agriculture now grapples with multiple challenges, including depletion of natural resources, erratic climate patterns, rising input costs, and food price volatility (Bhan and Behera, 2014). Soil erosion, intensive tillage induced loss of soil organic matter, degradation in soil structure due to profuse mechanization, soil salinity hazards, water and wind erosions, reduced rate of water infiltration, surface sealing and crusting, soil compaction, mono-cropping as well as erratic nature of climate, has led to a gradual decline in Total Factor Productivity (TFP) (Dam *et al*. 2024; Goldar *et al*. 2023; NBSS & LUP, 2023; Kumar *et al*. 2022; Chatterjee, 2017).

With only 2.4% of the world's land, India supports 18% of global population and 15% of livestock population, making land degradation a critical concern (Yitbarek, 2019; Nanda *et al*. 2019; Sreenivas *et al*. 2021). India has around 147 million hectares (Mha) of degraded land, including 94.0 Mha due to water erosion, 16.0 Mha from acidification, 14.0 Mha resulting from flooding, 9 Mha attributable to wind erosion, 6 Mha caused by salinity and the remaining 7 Mha from other external sources (Bhattacharyya *et al*. 2015). The Ministry of New and Renewable Energy has reported that approximately 500 million tonnes of crop residues are generated annually, out of which 125 million tonnes are burnt each year (Porichha *et al*. 2021). Burning agricultural leftovers for cooking and heating during winter months is a common phenomenon in Northern India, contributing to severe air pollution and health hazards (Bhuvaneshwari *et al*. 2019). These concerns call for an urgent and integrated action at every level in order to restore soil health, adopt sustainable agricultural practices, and ensure the long-term resilience of Indian agriculture. In response, alternative approach such as conservation agriculture (CA) is being promoted due to its ability to reverse the trend and bring back economic instability. CA practices like reduced tillage and crop residue incorporation have shown improvements in soil quality. Usage of legume cover crops or leguminous grasses in orchards enhances soil conservation, lowers cost and improves fruit quality (Ordóñez-Fernández *et al*. 2018). Alley cropping is another innovation in CA that offers productivity as well as economic and environmental benefits to producers (Soliman *et al.* 2022).

Cereal-based farming dominates the Southern Telangana Zone (STZ), accounting for nearly 40% of overall cereal production in India (Nthebere *et al*. 2022). However, Telangana faces significant land degradation, with 25% of its total geographic area (TGA) classified as degraded, resulting in a degradation cost of US$ 835 million (Dayakar, 2021). The state witnesses a moderate rate of soil erosion at 5–10 Mg ha^{-1} yr^{-1} (Biswas *et al*. 2015), which significantly contributes to crop land degradation. Moreover, the prevalence of rainfed agriculture makes the region particularly susceptible to soil erosion, which undermines agricultural productivity. Keeping these in view, the present study attempts to examine the economic impact of conservation agriculture on small and marginal households in Telangana state of India.

MATERIALS AND METHODS

A comparative study has been conducted between conservation (CA) and traditional farming (TF) practices for the predominant paddy-maize cropping system in Telangana, India, over 2019-20 and 2020-21. Mancherial and Warangal-Rural districts in Telangana were purposively chosen due to the presence of both conservation and conventional farmers. A total of 200 farm households (100 conservation and 100 conventional) were selected using Simple Random Sampling without Replacement Method. The study was structured around two specific objectives. The first objective was to assess the socio-economic variability among farm households practicing conservation and conventional agriculture. The parameters taken into consideration are age, level of education, operational holding, return from non-farm income sources, total assets, gross return from the crops and animals, total household consumption per annum, etc. Simple descriptive statistics such as mean and standard deviation have been used to summarize the data. The second objective aimed to evaluate the economic impact of CA over TF, using Bisaliah decomposition and Difference-in-Differences (DiD) technique in order to estimate the spatial and temporal effects on crop productivity. Informations were collected on inputs such as seed, NPK, organic manure, irrigation, PPC, machine labour, bullock labour and human labour. Since rice is the common crop in all cropping systems, the yields of other crops in the cropping systems need to be converted into rice-equivalent yield with the following equation;

$$\text{Rice-equivalent yield} = \text{Yield of other crop} \times \frac{\text{Price of other crop}}{\text{Price of rice}}$$

In order to evaluate the economic impact of conservation agriculture over conventional farming, Bisaliah's (1977) method of decomposition has been employed to assess changes in productivity over two consecutive years. Thus, there are two hypotheses proposed where the null hypothesis is set as:

H_0: There is no significant difference in paddy-maize system productivity under conservation agriculture as compared to conventional farming in Telangana

The corresponding alternative hypotheses would be H_1

H_1: There is a significant difference in paddy-maize system productivity under conservation agriculture as compared to conventional farming in Telangana

To sort out the influence of technology and resource usage efficiency from system productivity change, the Cobb-Douglas production function has been quantified for both the farming situations.

$$Y = aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}X_6^{b6}X_7^{b7}u_i \qquad \ldots(1)$$

The production function was determined on a per-hectare basis as the purpose is to compare productivity differences per hectare. Where, Y is the crop yield (kg ha^{-1}); X_1 is the quantity of seed used (kg ha^{-1}); X_2 is the quantity of NPK used (kg ha^{-1}); X_3 is the quantity of Organic manure used (kg ha^{-1}); X_4 is irrigation hours used (hour ha^{-1}); X_5 is the quantity of plant protection chemicals used (gm/ml ha^{-1}); X_6 is the amount of machine labour used (hour ha^{-1}); X_7 is the quantity of human labour used (man-days ha^{-1}); u_i is a random disturbance term in conformity by the ordinary least squares assumptions; b_i is a regression coefficient or factor contributions of respective parameters; a is a scale parameter or intercept. To determine structural differences, separate regressions for CA and TF are estimated;

$$LnY_{cons} = Ln\beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \beta_4 LnX_4 + \beta_5 LnX_5 + \beta_6 LnX_6 + \beta_7 LnX_7 + u_{cons} \qquad \ldots(2)$$

$$LnY_{conv} = Ln\alpha_0 + \alpha_1 LnX_1 + \alpha_2 LnX_2 + \alpha_3 LnX_3 + \alpha_4 LnX_4 + \alpha_5 LnX_5 + \alpha_6 LnX_6 + \alpha_7 LnX_7 + u_{conv} \qquad \ldots(3)$$

$$LnY_{pooled} = Ln\,\gamma_0 + \gamma_1 LnX_1 + \gamma_2 LnX_2 + \gamma_3 LnX_3 + \gamma_4 LnX_4 + \gamma_5 LnX_5 + \gamma_6 LnX_6 + \gamma_7 LnX_7 + \gamma_8 LnX_8 + u_{pooled} \qquad \ldots(4)$$

Equation (2) and equation (3) represent the multiple regression equations for farm households practicing conservation and conventional agriculture. Equation (4) represents the pooled regression model, including conventional and conservation cultivators by introducing a dummy variable (X_8).

The total difference in productivity was decomposed as follows:

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

Where, the first term $[Ln\beta_0 - Ln\alpha_0]$ represents the neutral technology gap (constant term difference means technology under constant return to scale); the second term $[LnX_{i\,conv}(\beta_i-\alpha_i)]$represents the non-neutral technology gap (technology under varied return to scale); the third term $[\beta_i Ln(X_{i\,cons}/X_{i\,conv})]$ represents the input-use difference effect (adjusted for relative change in input use between two farming situation) and lastly, final term [u_{cons} – u_{conv}] captures random error (unexplained variation) (Bisaliah, 1977).

Difference-in-Differences (DID or DD) approach, a type of quasi-experimental research design, has been utilized to evaluate the outcomes of groups influenced by different factors over distinct time periods. The change in outcomes before and after the intervention is calculated for the treatment group (farmers practicing conservation agriculture), and this change is then adjusted by subtracting the corresponding before-and-after change observed in the control group (traditional farmers) (Manjusree *et al*. 2021). Indicators used to assess the impact included quantity of seed, NPK, organic manure, irrigation hours, PPC, machinery labour, human labour. Its mathematical form can be written as:

$$y_{it} = \gamma_{s(i)} + \lambda_t + \delta I(\ldots) + \varepsilon_{it}$$

Here, y_{it} represents the dependent variable (SREY) for individual i (farming situations) overtime t, where t_1 = 2019-20 and t_2 = 2020-21. The term $s(i)$ denotes the group to which i belongs, either the conservation or the conventional farming situation. The notation $I(...)$ represents a dummy variable that equals to 1 for conservation farming and 0 for conventional farming situation. In a plot of time versus y by group, γ_s represent the vertical intercept for the graph corresponding to group s (conservation or conventional farming situation). The term λ_t captures the time effect between two farming situations under the parallel trend assumption. δ measures the change in effect of conservation farming over conventional, while $\boldsymbol{\varepsilon}_{it}$ denotes the residual term (Wing *et al*. 2018). The DID method can be applied as shown in the table 1 below, with the lower right cell representing the DID estimator.

Table 1: The DID method

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 for conservation farming; s = 2 conventional farming, 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.*

RESULTS AND DISCUSSION

The socio-economic changes between households practicing CA and TF in Telangana over two consecutive years reveal that most of the farmers are marginal, with operational holdings of around 0.48 ha. in both these farming situations. The average annual non-farm income is higher in CA (₹ 6795/-) compared to TF (₹ 5600/-). Land in this region is valued at 15-20 lakh per acre for agricultural use and ₹ 20-25 lakh per acre for residential purposes. Additionally, the average asset valuation, including land, well, dwelling house and farm machinery, has been estimated at ₹ 33.26 lakh for CA and ₹ 35.11 lakh for TF. The lower valuation of assets (5.27% less) among CA compared to TF can be attributed to their location in more remote village areas, fragmented land holdings, and lower valuation of land (6.32%). However, possession of farm machinery was found to be at par with traditional households during the survey. Households following CA have earned an average annual return of approximately ₹ 1,09 lakh, which is ₹ 15,000 more than that of TF. However, annual average consumption expenditure exhibited no such notable variations between these two types of farm households (Table 2).

Table 3 visibly depicts a substantial yield gap between CA and TF during the first year of experimentation (2019-20), where the yield gap in paddy was registered at 414 kg/ha, followed by maize (259 kg/ha) and the combined paddy-maize cropping sequence (591 kg/ha). This yield gap has further widened in the succeeding year (2020-21) to 556 kg/ha for paddy, 510 kg/ha for maize and 1025 kg/ha for the paddy-maize cropping sequence, respectively. CA consistently outperformed TF, yielding 485 kg/ha more for paddy, 385 kg/ha more for maize and 808 kg/ha more for the paddy-maize cropping sequence when pooled over two years. Further, the yield of the paddy, maize and paddy-maize cropping sequence has increased by 6.0%, 5.99% and 7.24%, respectively, under CA during experimental periods, which is quite higher than that of TF (1.98%, 1.98%, and 2.65%, respectively). The findings align with the study by Nthebere *et al*. (2024) which documented enhanced productivity under CA in Telangana.

The results relating to the overall comparative economics of the paddy-maize cropping sequence show that CA with lesser cost of cultivation and

Table 2: Socio-economic change in descriptive statistics of households under CA and TF in Telangana pooled over 2019-20 and 2020-21

Particulars	CA	TF	Relative change (%)
No. of observations	200	200	—
Total operational holding (ha.)	0.48	0.48	0.00
Non-farm income (₹/year)	6795	5600	21.33
Total valuation of current assets (including land, well, dwelling house, and farm machinery) (₹)	3325992	3511091	-5.27
Gross return from crops (₹/year)	102517	88168	16.27
Total consumption expenditure (₹/year)	57916	56890	1.80
Total Annual Income of farm-family (₹/year)	109312	93768	16.58

Table 3: Relative change in yield of paddy, maize and paddy-maize cropping sequence (kg/ha) under two years of farming practices in Telangana

Farming type	2019-20			2020-21			Pooled			Relative change (%) over two years		
	Paddy Yield	Maize Yield	Paddy-Maize Yield	Paddy Yield	Maize Yield	Paddy-Maize Yield	Paddy Yield	Maize Yield	Paddy-Maize Yield	Paddy Yield	Maize Yield	Paddy-Maize Yield
Conservation	3331	6143	9126	3531	6511	9787	3431	6327	9456	6.00	5.99	7.24
Conventional	2917	5884	8535	2975	6001	8762	2946	5942	8648	1.98	1.98	2.65
Yield gap	414 (14.19)	259 (4.40)	591 (6.92)	556 (18.68)	510 (8.49)	1025 (11.69)	485 (16.46)	385 (6.47)	808 (9.34)	34.29	96.91	73.43

Note: *Figure in the parentheses indicates percent change in yield under conservation farming practice over conventional practice.*

Table 4: Relative change in economics for paddy-maize cropping sequence under CA and TF in Telangana over 2019-20 and 2020-21

Particulars	CA			TF			Relative change (%)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
System cost of cultivation (INR/ha)	96890	103178	100034	109349	115900	112625	-11.39	-10.98	-11.17
System gross return (INR/ha)	200215	222687	211451	186297	198778	192537	7.47	12.03	9.82
System net return (INR/ha)	103325	119510	111418	76947	82878	79913	34.28	44.20	39.42
Return-Cost ratio	2.07	2.16	2.12	1.70	1.72	1.71	21.32	25.87	23.97

higher returns, was more efficient than TF in the study region. The paddy-maize cropping system has emerged as a profitable alternative to the traditional rice-rice cropping sequence in this region over the years (Swamy *et al.* 2018). Farmers have enjoyed 9.82% greater return under CA with curtailment of 11.17% cost, which has resulted in a gargantuan increase in profit margin (39.42%) and return-cost ratio (23.97%) over TF (Table 4). However, a recent study on the sustainable intensification of the paddy-maize cropping system under conservation farming in Southern India has revealed that transplanted rice with conventional tilled maize fetched the highest net returns and return-cost ratio over the direct wet-seeded rice with resource conservation (Tuti *et al*. 2022).

Regarding changes in input use for the paddy-maize cropping system, both CA and TF have followed similar patterns over the years with profound variations in their farming approaches. It has been observed that CA requires less irrigation, fewer plant protection chemicals, reduced machine labour and lower workforce input in comparison to TF. Due to the adoption of minimum tillage, comparatively less usage of machine labour has been observed under CA. The overall paddy-maize cropping sequence has registered 22.18% less mechanization under conservation agriculture, along with a steady decline in workforce requirement (5.43%). Additionally, the application of more organic matter (32.18%) in conservation farming practices could regain the inherent fertility status of soil, mitigating the ill effect of chemical fertilizer (Table 5).

Organic amendments are beneficial in improving soil quality and rice yield by increasing soil organic carbon and microbial biomass, while green manure has the ability to perk up the availability of N in soil, aiding rice uptake but also enhancing CH4 emissions (Jia *et al*. 2024). It has played a significantly positive role in the productivity of maize too (Wang *et al*. 2017) followed by workforce requirements in CA, while seed exerts a significant negative impact on productivity under TF. Dummy variables have ensured its prominence in the regression, exhibiting a statistically significant difference between two packages of practice. Overall, paddy-maize system productivity has been influenced by optimum use of organic manure, assured irrigation facilities and adequate requirements of the workforce under CA. In TF, coefficients of all inputs have significantly impacted system productivity of the paddy-maize cropping sequence, either positively or negatively. Among all the used inputs, only quantity seed use and machine labour hours had a negative impact on system productivity, while the remaining inputs contributed positivity towards productivity (Table 6).

The Bisaliah decomposition analysis of the paddy-maize cropping system under CA depicted a 6.92% and 11.70% successive gain in system productivity, while estimated gains were 6.69% and 11.07%, respectively. These improvements are mainly due to positive technology differences of 10.34% in 2019-2020 and 17.00% in 2020-21. The positive changes are driven by neutral technology under constant returns to scale (coefficient differences of regression intercept), which offset the negative effects of non-neutral technology gap under varied returns to scale. However, substitution of quality input has had a negative impact on productivity, mainly due to operation-wise surplus labour engagement in the field, which can diminish the overall labour efficiency. However, the current study begs to differ with the economic impact assessment of CA in West Bengal, where substitution of quality inputs was the prime contributor behind productivity growth (Chatterjee *et al.* 2020). The state of technology in the form of changing methods of cultivation practices became the prime contributor behind the

Table 5: Relative change in various input use for paddy-maize cropping sequence under CA and TF in Telangana over 2019-20 and 2020-21

Particulars	**CA**			**TF**			**Relative change (%)**		
	2019-20	**2020-21**	**Pooled**	**2019-20**	**2020-21**	**Pooled**	**2019-20**	**2020-21**	**Pooled**
No. of observations	100	100	200	100	100	200	—	—	—
System Quantity of seed (kg/ha)	405.66	413.78	409.72	341.97	348.81	345.39	18.62	18.62	18.62
System Quantity of NPK (kg/ha)	1024.87	1103.03	1063.95	950.05	1021.04	985.55	7.88	8.03	7.96
System Quantity of organic manure (q/ha)	14.05	14.11	14.08	10.65	10.65	10.65	31.93	32.43	32.18
System Irrigation (hour/ha)	154.77	161.28	158.03	219.74	229.10	224.42	-29.57	-29.60	-29.59
System Quantity of PPC (g/ml/ha)	12419.94	12577.95	12498.95	12869.93	13036.84	12953.39	-3.50	-3.52	-3.51
System Machine labour (hour/ha)	23.23	23.23	23.23	29.86	29.86	29.86	-22.18	-22.18	-22.18
System Bullock labour (pair-hour/ha)	0	0	0	0	0	0	0	0	0
System Human labour (person-days/ha)	100.36	104.38	102.37	106.13	110.37	108.25	-5.43	-5.43	-5.43

acceleration of paddy-maize system productivity under CA in Telangana (Table 7).

Finally, the Difference in Differences (DiD) method has been applied to judge the impact of CA over TF across 2019-20 and 2020-21 on the paddy-maize cropping system in Telangana state in India. The results reveal that, over the two years, the paddy-maize cropping system in this region has exhibited

Table 6: Regression estimates of yield and inputs for paddy-maize cultivation under CA and TF in Telangana over 2019-20 and 2020-21

Particulars	Parameters	2019-20			2020-21		
		CA households	TF households	Pooled	CA households	TF households	Pooled
No. of farm households	N	100	100	200	100	100	200
Intercept	a	8.24**	4.43**	4.68**	6.81**	4.47**	4.36**
System quantity of seed (kg/ha)	X_1	0.02	-0.14**	-0.06*	0.01	-0.15**	-0.06*
System quantity of NPK (kg/ha)	X_2	-0.08	0.17*	0.04	-0.06	0.16*	0.04
System quantity of organic manure (q/ha)	X_3	0.05*	0.05*	0.05**	0.07**	0.05*	0.07**
System Irrigation (hour/ha)	X_4	0.13*	0.14**	0.14**	0.13**	0.14**	0.13**
System quantity of PPC (g/ml/ha)	X_5	-0.15	0.20*	0.12*	-0.12	0.19*	0.12*
System machine labour (hour/ha)	X_6	-0.08	-0.17*	-0.12**	-0.01	-0.15*	-0.07
System human labour (person-days/ha)	X_7	0.48**	0.45*	0.61**	0.66**	0.41*	0.66**
Dummy variable for pooled analysis	—	—	—	0.12**	—	—	0.17**
R square	R^2	0.48	0.52	0.67	0.54	0.55	0.83
Adjusted R square	Adj. R^2	0.45	0.48	0.65	0.50	0.51	0.82
F value (p = 0.05)	F	12.35	14.00	47.67	15.26	15.91	114.55
F critical (p = 0.05)	F	1.98	1.98	1.97	1.98	1.98	1.97

Note: **, ** significant at p <0.05 and p <0.01 respectively.*

Table 7: Bisaliah decomposition for paddy-maize cropping sequence under CA and TF in Telangana over 2019-20 and 2020-21

Particulars	2019-20	2020-21
	Difference between CA and TF (%)	Difference between CA and TF (%)
(I) Total observed difference in system productivity (kg/ha) between conservation and conventional practices	6.92	11.70
1. Due to technology difference	10.34	17.00
(a) Neutral technological gap	380.71	207.59
(b) Non-neutral technological gap	-370.37	-190.59
2. Gap attributable to relative change in input use level weighted by the slope coefficient of productivity function	-3.65	-5.93
(a) Seeds	0.30	0.13
(b) NPK fertilizer	-0.64	-0.49
(c) Organic manure	1.29	1.98
(d) Irrigation	-4.49	-4.50
(e) Plant protection chemicals	0.52	0.41
(f) Machine labour	2.06	0.19
(g) Human labour	-2.69	-3.66
(II) Total estimated difference in system productivity (kg/ha) between conservation and conventional farming practices	6.69	11.07
(III) Error	0.23	0.63

Table 8: Covariates and coefficients in DiD (Paddy-Maize cropping sequence)

Variable(s)	Coefficients	Standard Error	t	p> ǀ t ǀ
Quantity seed	-1.300	0.388	-3.351	0.001
Quantity NPK	0.275	0.242	1.137	0.256
Quantity organic manure	54.050	8.318	6.498	0.000
Irrigation hours	5.401	0.916	5.899	0.000
Quantity PPC	0.077	0.025	3.046	0.002
Machinery labour	-32.133	9.140	-3.515	0.000
Human labour	57.282	6.052	9.466	0.000

Table 9: Outcome of DiD (Paddy-Maize cropping sequence)

Outcome variable(s)	SREY (kg)	Standard Error	ǀ t ǀ	p> ǀ t ǀ
Before Difference (T-C)	972.436	119.019	8.17	0.000***
After Difference (T-C)	1432.336	121.832	11.76	0.000***
Difference in Differences	459.900	52.335	8.79	0.000***

Note: *R square = 0.81; Inference: *** p <0.01; ** p <0.5; * p <0.1.*

459.90 kg more production per hectare as compared to TF. Notably, the yield gap between the two farming situations has widened from 972.44 kg/ha in 2019-2020 to 1432.34 kg/ha in 2020-2021, highlighting growing advantage of CA over time. As per the factors responsible for the dominance of CA over TF, a 5.43% reduction in man-day requirement has exhibited a higher significant positive impact on gain in paddy-maize system productivity, followed by a subsequent increase (30.0-32.0%) in organic manure applied to the field, which would subdue the effect of inorganic fertilizer application by the farmers (~8.0%). Findings are well acquainted with the study in Bengal, where a subsequent rise in the application of organic matter (68.2%) in soil has reduced NPK application by 9.32% (Chatterjee *et al.* 2022). Furthermore, the reduction in machinery usage (~22.0%) under reduced tillage conditions has had a significant negative impact on changes in system productivity over the years (Tables 8 and 9).

In view of the foregoing findings and discussion, it reveals a marked positivity of CA in Telangana that could ensure the betterment of productivity and returns while ensuring farm-family income and livelihood in a sustainable manner.

CONCLUSION

CA is a vital farming practice since it aims at conserving and efficiently utilizing natural resources through an integrated management system involving soil, water, and biological resources combined with external inputs. It contributes to environmental conservation as well as sustainable agricultural production, making it a resource-efficient and resource-effective farm. This is one of the technologies that farmers are adopting to have sustainable and environmentally friendly agricultural production. Farmers following CA reveal a 16.58% betterment of total farm-family income followed by 9.34% increase in paddy-maize system productivity and a subsequent upsurge of 23.97% return-cost ratio over TF. The results demonstrated the potential of CA to ensure economic and social sustainability for the future generations in Telangana.

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