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Determinants of Conservation Agriculture for Sustainable Intensification (CASI) outscaling—a study in Coochbehar district of West Bengal, India

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Abstract The Sustainable and Resilient Farming Systems Intensification in the Eastern Gangetic Plains (SRFSI) project attempted to outscale Conservation Agriculture for Sustainable Intensification (CASI) practices in North Bengal. An exploratory study conducted during 2018–19 assessed adoption and the determinants of outscaling CASI. The SRFSI farmers allocated about 40% of their gross cropped area to CASI, and non-SRFSI farmers only 1%; both allocated more acreage in the winter. Adoption is influenced by proximity to resources, awareness of CASI, plot size, and women's participation. To enhance adoption, mechanical hubs must be established near farms to provide the resources needed timely and effectively.

Keywords Conservation Agriculture for Sustainable Intensification (CASI), conservation agriculture (CA), adoption, determinants, outscaling strategy

JEL Code Q2

In India, during the green revolution in the late 1960s (Fujita 2010), improved, or modern, agriculture supplanted the erstwhile traditional method of farming (Sidhu and Grewal 1990). Using chemical fertilizers, irrigation water, and high-yielding varieties improved the productivity of crops, and the agricultural output, especially food grain production, increased dramatically. The 45% increase in the food production per capita since the green revolution till 2015 (Chand 2017) has made the nation comfortably self-sufficient.

The focus of the green revolution was on immediate returns—production, not yield—rather than long-term, sustainable gain; and rigorous tilling, and the indiscriminate and injudicious use of fertilizers, water, and chemicals, became a normal, though unfortunate, practice in the Indian farming system. Soil and environmental health, and the aspect of economic efficiency, were grossly ignored. The net farm income fell, as a result, in some cases below zero; soil and environmental health deteriorated gradually; crop productivity stagnated (the yield gap hovers around 30–40% of the potential frontier); and the economic efficiency became poor. Land and factor productivity have declined, and the gains from the green revolution have been plateauing (Ramasamy 2004)—dissuading the young generation from farming (IFAD 2012; Paisley 2013) and forcing members of farm families to seek off-farm employment (Balodi et al. 2015).

Sustainable growth in agriculture, therefore, requires a paradigm shift: from conventional, input-intensive farming to environment-friendly farming that augments net income (Chand 2017). Transgenic and genetically modified crops have the potential to improve the yield gain substantially, and researchers favour the proposition, but such farming cannot be adopted because the public apprehension over human health and environmental safety is too strong (Chand 2017). The feasible options are environment-friendly yet technically efficient farming systems: alternative agronomic technologies like direct seeded rice, zero tillage, raised bed plantation, and transplanting with rice transplanter (Kassam, Friedrich, and Derpsch 2018; Knapp and Heijden 2018; Laxmi and Erenstein 2006).

The northern tract of West Bengal, spread over 21,855 square kilometres, is known as North Bengal. Agriculture, the primary sector, contributes 30–33% towards the net district domestic product on an average in the districts of North Bengal (Bureau of Applied Economics and Statistics 2015). The region is economically dormant. Agricultural performance has historically been poor. Crop yield lags behind the corresponding national figures; the growth rates have been low, especially after the 1990s (Lepcha, Nag, and Das 2020); and the average farm income is abysmal. The circumstances have been exacerbated by the sustained rise in population, climatic aberration (especially, erratic rainfall), and the vulnerable marketing context (price instability, for example). The farming community is in search of an alternative farming practice.

The Sustainable and Resilient Farming Systems Intensification in the Indo-Gangetic Plains (SRFSI) project attempts to reverse these negative trends by introducing the principles of conservation agriculture in these areas. The SRFSI project is a collaboration of Uttar Banga Krishi Viswavidyalaya and International Wheat and Maize Improvement Center (CIMMYT), and it is funded by the Australian Centre for International Agricultural Research. Since 2013–14, the SRFSI project has been trying to popularize the principles of conservation agriculture among the farming community by conducting participatory demonstration trials and adopting extension approaches (farmers' field days, meeting/training programmes, and exposure visits). The overall goal—sustainably intensify the cropping system in the region—is called conservation agriculture for sustainable intensification (CASI).

Conservation agriculture for sustainable intensification can preserve soil health, reduce labour unemployment, lower total variable costs significantly, and enhance farm income (Kassam, Friedrich, and Derpsch 2018; Kumar et al. 2011; Laxmi and Erenstein 2006). The spillover effects of these inherent merits can improve the livelihood of the farming community. We undertook these efforts with a variety of clientele groups: some conducting demonstration trials (trial farmers) and others trying to replicate or outscale the method of cultivation (with or without material support).

This study analyses the success of the attempt to persuade the clientele groups and farming fraternity of the merits of the technology and its adoption. In addition, the study attempts to understand the factors, both enabling and constraining, underlying the attempt made thus far.

Materials and methods

Since 2013–14, the SRFSI intervention has been taking place in 12 blocks in Coochbehar district of West Bengal. We conducted the study in 5 nodes over 3 blocks in the district. Each node is constituted of a village and its neighbouring areas, covering about 1,200–1,500 households. About 14% of the farming households in the district live in the study area (Department of Planning and Statistics 2016).

Using a pre-tested survey questionnaire, we conducted a one-to-one household survey in 2018–19. We collected data from two categories of respondent farmers: SRFSI farmers associated directly with the CASI project activities in the form of conducting or outscaling demonstration trials; and non-SRFSI farmers not directly associated with SRFSI research/extension activities. We used the face-to-face interview method to elucidate the data. We employed the simple random sampling without replacement (SRSWOR) technique in selecting the sample respondents randomly from 3 of the 12 blocks in the district (Department of Planning and Statistics 2016).

The sample comprises 341 respondents (215 SRFSI farmers and 126 non-SRFSI farmers). We calculated, for both categories, the descriptive statistics for the major demographic, socio-economic, and attributive traits. We subjected the data to multivariate analysis (Mahalanobis squared distance, D^2) for identifying the group/category difference based on the selected traits as a whole (Dasgupta 1993). Following Reincke et al. (2018), we ran a regression model, composed of applied indicators and constructed variables out of the household survey data, to find the main influences on the adoption of CASI. We employed the ordinary least squares (OLS) method of multiple regression analysis (Gujarati 2006; Koutsoyiannis 1987). The core equation to be estimated is

$$Y_i = \beta_0 + \beta_i X_i + \varepsilon_i$$

where

the unit of observation is the household,

Y_i is percentage of GCA allocated under CA method,

X_i is the vector of determinants for CA adoption,

β_i is the regression co-efficient for ith determinant, and

ε_i is the stochastic disturbance term.

To avoid selecting autocorrelated independent variables (Chatfield 2005), we ran the Durbin–Watson test on the preselected variables (Field 2013), and we included the variables only if $2.5 > d > 1.5$, $d = 2$ indicating the absence of autocorrelation. We tested the selected variables for multicollinearity identifying variance inflation factors (VIF). We excluded the "investment capacity" variable because its VIF > 10 (Koutsoyiannis 1987; Montgomery and Peck 1982). We used statistical software packages like SAS, SPSS (Field 2013), and Systat 13.

Results and discussions

The size of farming families averages 4.47 (Table 1), similar to the current trend of nuclear families in the country (Office of the Registrar General & Census Commissioner 2011; UN 2017). Adult men and women are educated up to the 8th standard only, but the current trend among boys and girls for school going is quite encouraging. About 80% of farming families have food sufficiency for more than 9 months, and about 33% of their income is from non-farm sources. The decision-making head of a family is around 45 years old on average; the age may affect the decision to adopt CASI technologies. We used the Mahalanobis D^2 statistics to identify the differences between SRFSI and non-SRFSI farmers on the basis of these "general traits". The magnitude of D^2 statistics (0.23) shows that the two groups differ significantly ($p = 1.6$), and SRFSI farmers are better off than non-SRFSI farmers.

The size of a cropping plot is around 0.19 ha (0.23 ha for SRFSI farmers and 0.14 ha for non-SRFSI farmers) (Table 2). The small farm size is an inherent hindrance for mechanization (Kapur et al. 2017; Raina et al. 2018). About 68% of the land is fully irrigated on an average, but electricity powers only 18%, and diesel is used to irrigate the rest. In persuading the farming community to adopt a new technology, a crucial role is played by their proximity to resources/services like existence of input shops, soil testing laboratory, office of the local agricultural extension agency, and market for output disposal. On an average, only 7.44% of SRFSI farmers and 1.59% of non-SRFSI farmers, or 5% of the total respondent farmers, live within 1 kilometre of the resources they require. The area is backward on feminization; women's participation in the farming practices hovers around 2.29 man-hours per day round the year.

The SRFSI farmers are better off; however, the Mahalanobis D^2 statistics (0.47) identifies a significant

Table 1 Farming community demographics by category

Feature	SRFSI farmers (n = 215)	Non-SRFSI farmers (n = 126)	Overall (n = 341)
Farm family size	4.41	4.59	4.47
Standard of education of farm family head (years of schooling)	8.61	7.71	8.27
Age of decision-making family head (years)	44.81	45.98	45.24
Family food sufficiency for more than 9 months (%)	78.61	84.12	79.16
Standard of education of farm females (years of schooling)	7.97	6.96	7.60
Share of off-farm sources in farm family income (%)	29.29	25.37	27.84
Current trend in school going among children (%)	79.97	86.75	82.48

Source Primary survey data

Table 2 Farming community -other general features by category

Feature	SRFSI farmers (n = 215)	Non-SRFSI farmers (n = 126)	Overall (n = 341)
Size of farm holding (ha)	0.92	0.93	0.92
Size of operational plot (ha)	0.23	0.14	0.19
Extent of medium to low-lying agricultural land (%)	46.95%	40.69%	44.64%
Extent of fully irrigated farmland (%)	64.86	72.30	67.61
Extent of electricity connection in field (%)	21.39	11.90	17.89
Resource proximity within a km (%)	7.44	1.59	5.28
Effective member for farming (%)	45.23	42.59	44.26
Female participation in farming (hours per day)	2.36	2.18	2.29

Source Primary survey data

Table 3 Crops, cropping intensity, and void area by season

Feature	SRFSI farmers (n = 215)	Non-SRFSI farmers (n = 126)	Overall (n = 341)
Cropping intensity (%)	181.66	173.18	178.52
Major crops	Kharif (aman) paddy, winter maize, potato, wheat, lentil, summer (boro) paddy, jute, vegetables		
Void area in kharif season (% of net cultivable area)	9.76%	5.99%	8.37%
Void area in rabi season (% of net cultivable area)	26.61%	43.31%	32.78%
Void area in pre-kharif season (% of net cultivable area)	81.98%	77.52%	80.33%

Source Primary survey data

distance ($p = 0.01$), or difference, between the groups. The SRFSI farmers use their cultivable area more intensively, but the two groups seem to be relatively and significantly ($p = 10.0$) closer ($D^2 = 0.099$) on these features (Table 3). About 80% of the cultivable land lies void and unutilized in the summer, or pre-kharif season. The cropping intensity lies well below the 200% mark (it averages 178.52%), indicating a void in the net cultivable area (0.92 ha) in all the cropping seasons—rainy (kharif), winter (rabi), and summer (pre-kharif or kharif 1). The principal crops are kharif paddy (locally, aman), winter (rabi) maize, potato, wheat, lentil, summer paddy (locally, boro), jute, and vegetables (Table 3).

SRFSI intervention

The practices of conservation agriculture (CA) are thought to be ideal in improving the current physical, economic, and environmental aspects of farming (Berger, Friedrich, and Kienzle 2010; ICARDA 2012; Joshi 2011; Kassam, Friedrich, and Derpsch 2018; Knapp and Heijden 2018; Laxmi and Erenstein 2006). To demonstrate the merits of conservation agriculture, participatory trials were conducted in a limited area for a few selected farmers at each SRFSI project site for three consecutive years (2014–15, 2015–16, and 2016–17). Attempts were made in 2014–15 to introduce CASI practices in major crops like kharif (aman) paddy, wheat, rabi maize, lentil, summer (boro) paddy, and jute. About a year later, the coverage was expanded, or outscaled, to the adjoining areas where feasible.

The SRFSI farmers practise conservation agriculture on about 40% of their gross cropped area and the non-SRFSI farmers on about 1% (Table 4). Adoption is not uniform: kharif paddy farmers practise conservation agriculture on only 10.57% of their net cultivable area

Table 4 Extent of CA coverage in allocated acreage under attempted crops

Feature	SRFSI farmers (n = 215)	Non-SRFSI farmers (n = 126)	t-value	Significance (probability level)	Overall (n = 341)
Extent of CASI coverage in gross cropped area (%)	39.98	1.15	21.84	<0.0001	25.63
Major CA crops	Kharif (aman) paddy, wheat, rabi maize, lentil, summer (boro) paddy, jute				
Extent of CASI in kharif paddy acreage (% of area allocated per farm)	16.76%	0.00%	7.39%	<0.0001	10.57%
Extent of CASI in wheat acreage (% of area allocated per farm)	95.50%	12.60%	5.46%	<0.0001	64.87%
Extent of CASI in maize acreage (% of area allocated per farm)	95.35%	3.67%	24.88%	<0.0001	60.21%
Extent of CASI in lentil acreage (% of area allocated per farm)	72.25%	35.62%	5.59%	<0.0001	58.71%
Extent of CASI in summer (boro) paddy acreage (% of area allocated per farm)	49.39%	0.00%	8.38%	<0.0001	31.14%
Extent of CASI in jute acreage (% of area allocated per farm)	29.32%	0.00%	6.86%	<0.0001	18.49%

Source Primary survey data

(SRFSI farmers allocate 16.76% of their net cultivable area and non-SRFSI farmers a negligible percentage). Farmers who grow jute in the summer practise conservation agriculture on about 18.49% of their net cultivable area (SRFSI farmers allocate 29.32% of their net cultivable area and non-SRFSI farmers a negligible percentage). Adoption differs significantly ($p < 0.01$) by farmer category (Table 4).

Perception of CASI

To elicit the perception of farmers practising CASI directly or indirectly, we listed the advantages of practising conservation agriculture and asked the interviewees whether they agreed (fully/partially), did not agree, or had no idea. More than 90% of the SRFSI farmers (demonstration trial plus outscaled) are fully persuaded of the merits of conservation agriculture (Table 5).

The SRFSI farmers agreed that practising conservation agriculture reduced the cost of cultivation and the water requirement substantially while retaining or raising the yield of the main product and the by-product. The quality of their produce improved, raising the market price and improving the net farm income. A visual inspection suggested that the soil health improved, too. Practising conservation agriculture lets farmers

Table 5 Farmers' perception of conservation agriculture

Merits	Response of SRFSI farmers (n = 215)			Response of Non-SRFSI farmers(n = 126)			Overall (n = 341)		
	Agreed (%)	Not agreed (%)	No idea (%)	Agreed (%)	Not agreed (%)	No idea (%)	Agreed (%)	Not agreed (%)	No idea (%)
Cost saving?	94.18	1.61	4.20	19.00	3.00	78.00	66.40	2.13	31.47
Yield increased?	86.06	0.63	13.31	16.00	4.00	80.00	60.18	1.87	37.95
Improved grain quality?	90.25	1.97	7.78	17.00	3.00	80.00	63.18	2.35	34.46
Water saving?	87.64	3.96	8.40	16.00	4.00	80.00	61.17	3.97	34.86
Time saving?	92.44	2.74	4.82	19.00	4.00	77.00	65.30	3.21	35.18
Improved soil health?	84.13	3.04	12.83	15.00	4.00	81.00	58.59	3.39	38.02

Source Primary survey data

advance the sowing/planting season and take up the subsequent crop earlier, solving the migration-related labour crisis in the peak period. The practice of conservation agriculture requires the use of machinery (zero tillage seed drill, multi-crop planter, tractor) that farmers cannot afford. Some individuals or groups that own the machinery provide farmers access. The service providers see the demand as an agribusiness opportunity and seek to expand their business.

Despite their overwhelming preference for CASI, however, the farmers perceived problems in the field. We listed these problems and asked the interviewees whether they agreed (fully/partially), did not agree, or had no idea. About 50% of the SRFSI farmers are concerned about enhanced weeds, the complexity of the calibrating method, and non-uniform seed/plant dropping; about 80% of the non-SRFSI farmers had no idea; and about 12–13% are apprehensive about the reduced yield, emergence of new types of weed, and the enhanced compactness of soil (Table 6).

In the zero/reduced tillage crop cultivation protocol, the residue must be kept, the tillage eliminated or minimised; weeds will emerge, and the appropriate herbicides must be applied. When farmers try a new technology, apprehensions are natural; these will disappear if capacity-building and awareness campaigns are conducted to teach farmers to apply the correct dose of weedicide at the appropriate time and if they sustain the practice. In the case of zero tillage seed drill or rice transplanter, non-uniform seed sowing, or dropping of seedling, is a genuine mental hitch; it can be overcome with expertise in "machine driving" in the field. The machine operators need to consider if the soil condition is moist or dry and the size of the seed is small, medium, or large and calibrate accordingly. An experienced operator can enhance the possibility of uniform seed dropping manifold; in addition, simpler machinery must be developed.

The non-SRFSI farmers observed the demonstration or participatory trials, attended focus group discussions and field days, and discussed these with neighbouring farmers, and about 17% of them are persuaded of the potential benefits of conservation agriculture, but about 80% of them do not have any perception of its attributes. As the cost of cultivation escalates, farm income falls, the excessive use of chemical fertilizers reduces the soil fertility, and the labour crisis continues, this experience of CASI may help outscale it to newer areas and farming communities.

Determinants of CASI adoption

What determines the adoption of CASI? We use the OLS method of multiple regression analysis to list the possible factors with the expected sign/nature of effect (Table 7). The extent of adoption is

$$\text{CA adoption (\%)} = \frac{\text{CA acreage for all the crops for ith firm in an agricultural year}}{\text{GCA for ith firm in the same agricultural year}} \times 100$$

In our multiple regression model, the extent of adoption is the dependent variable. The non-SRFSI farmers are learning CA technologies; adoption is zero in most cases, and the estimate of regressors may mislead us.

Table 6 Issues that farmers perceive as problems

Merits	Response of SRFSI farmers (n = 215)			Response of Non-SRFSI farmers(n = 126)			Overall (n = 341)		
	Agreed (%)	Not agreed (%)	No idea (%)	Agreed (%)	Not agreed (%)	No idea (%)	Agreed (%)	Not agreed (%)	No idea (%)
More weed?	68.78	26.10	5.12	15.00	9.00	76.00	48.91	19.78	31.31
New weed?	47.84	46.72	5.44	1.00	7.00	92.00	30.53	32.04	37.43
Complex process?	64.61	22.58	12.81	18.00	5.00	77.00	47.39	16.09	36.52
Soil compact?	23.21	69.21	7.58	18.00	4.00	78.00	21.28	45.11	33.60
Non-uniform sowing?	71.19	10.46	18.34	19.00	4.00	77.00	51.91	8.07	40.02
Yield reduced?	20.76	68.62	10.62	2.00	22.00	76.00	13.83	51.40	34.77

Source Primary survey data

Therefore, we exclude these farmers from our regression analysis. Table 7 lists the independent variables we assume influence adoption; we include both quantitative and qualitative variables.

Earlier studies show that the adoption decision is influenced chiefly by demographic, socio-economic, topographical, institutional, and attitudinal factors (Chuchird, Sasaki, and Abe 2017). This study assumes that the adoption decision is influenced by demographic traits, socio-economic factors, institutional factors like proximity of "service" availability, behavioural instincts, and topographical factors.

The demographic traits are age of functional head, as a proxy of farming experience; educational standard of farm family as well as of family head, a critical parameter for rationality in decision-making; and extent and nature of participation of family members in farming, especially that of farm females, an indicator of "attachment" to the avocation.

The socio-economic factors are landholding size; average plot size, an indicator of the operational feasibility of a multi-crop planter machine; the extent of land irrigated round the year, a clue of the potential for improving cropping practices; cropping intensity; rice-equivalent yield (REY), as a measure of farming performance; and investment capacity.

The CASI technology involves mechanization—the use of multi-crop planters and zero tillage seed drill, for example—and we assume that the adoption decision is governed greatly by institutional factors like proximity of "service" availability.

Table 7 Determinants of CASI adoption

Variables	Description	Explanation	Assumed effect
Age_head	Age of the farm family head	Number of years	Negative
Ed_head	Education of farm family head	Number of schooling years	Positive
Ed_female	Highest education of farm females	Number of schooling years	Positive
Farm_effective	Participation of family member in farming	Percentage of total family size	Positive
Fem_farming_hrs	Participation of women in farming	Women's participation in farming (hours per day)	Positive
Fem_farming_nature	Farm female participation in farming	Nature of participation in farming (fully, partially)	Positive
Knowledge_CA	Existing knowledge of CA	Score : Very good, good, bad	Positive
Instit._visit	Frequency of visits to institutes	Score : Frequently, sometimes, never	Positive
Proximity-resc.	Availability of required CA resource	Score : <1 km, (1–2) km, (2–5) km and >5 km	Negative
Size_agril._land negative	Agricultural landholding	Total cultivable area in ha	Positive/
Plot_size	Size of farming plot (ha)	Size of individual plots in ha	Positive
Extent_up land	Extent of medium to high land	Percentage of total agricultural land	Positive
Extent_irrig. Land	Extent of fully irrigated land	Percentage of fully irrigated cultivable land	Positive
Cropping_intens	Intensity of cropping	Share of GCA to NCA	Positive
REY_diff	Rice equivalent yield (REY) difference	Difference in REY of major crops ($t\ ha^{-1}$)	Positive
Invest_capacity	Source of paid out capital/investment	Score : Own, (own + credit), credit	Positive
Benefit_CA	Perceived advantages of CA	Total score of all the perceived meritorious points on CA	Positive
Issues_CA	Perceived problems in CA methods	Total score of all the perceived problems/issues in CA	Negative

Source Primary survey data

Sometimes the intended clients, the farmers, are guided by behavioural instincts and attitudinal factors, such as perception of the complexities of CASI and problems like compactness of soil and greater weed infestation. Knowledge and experience bolster self-confidence; if family members visit extension institutes frequently, farmers are more likely to adopt CASI.

The CASI applies differently in upland than in lowlands, and we assume that topography is a factor of adoption.

We assigned relevant and reasonable scores to the responses— agree, partially agree, do not agree, and no idea—to qualitative variables for analysis. We used dummy variables (Montgomery and Peck 1982) to offset the effect of the variable on the response to some qualitative variables: frequency of visits by family members to relevant institutes or organizations; proximity to required resources, like ZT machines, tractors, and recommended agrochemicals, including fertilizers; and the existing knowledge of CASI. Our multiple regression analysis assumes that certain variables explain adoption, and our assumptions are confirmed by the values of our tests: R^2 (0.51); F (14.04), which is highly significant ($p < 1$); and the Durbin–Watson statistic (Table 8).

The decision to allocate crop acreage to CASI is influenced significantly and positively by the number of years of schooling, knowledge of CASI, the decision-making head's habit of visiting institutes and organizations frequently, the nature and extent of women's participation in farming, proximity to the inputs required and the perceived advantages of CASI.

Table 8 Results of multiple regression analysis

Variables	Unstandardized coefficients		Standardized coefficients	*t*-value	Significance (probability level)	Variance inflation factor
	Beta	Standard error	Beta			
Intercept	-8.079	11.625	-	-0.698	0.596	-
Age of farm family head (years)	0.033	0.120	0.016	0.279	0.781	1.284
Education of farm family head (schooling years)	0.770	0.318	0.142	2.422	0.016	1.366
Participation of women in farming ((hrs day^{-1})	2.287	1.003	0.167	2.280	0.024	2.138
Full female participation in farming (score)	5.828	3.367	0.124	1.731	0.085	2.046
Existing good knowledge base on CA (score)	9.941	4.558	0.259	2.181	0.030	5.602
Existing medium knowledge base on CA (score)	5.972	4.243	0.152	1.407	0.161	4.633
Frequent of visiting relevant institutes (score)	10.833	3.081	0.280	3.516	0.001	2.528
Intermittent visiting relevant institutes (score)	4.227	2.829	0.103	1.494	0.137	1.888
Availability of required CA resource (<1.0 km)	24.118	4.992	0.311	4.831	0.000	1.655
Availability of required CA resource (1–2.0 km)	13.289	3.050	0.334	4.356	0.000	2.333
Availability of required CA resource (2–5.0 km)	4.949	2.880	0.127	1.719	0.087	2.171
Agricultural land holding (ha)	-0.875	0.322	-0.169	-2.719	0.007	1.531
Size of farming plot (ha)	1.106	0.715	0.086	1.546	0.124	1.241
Extent of medium to high land (percentage)	0.029	0.047	0.046	0.629	0.530	2.153
Extent of fully irrigated land (percentage)	0.045	0.044	0.067	1.039	0.300	1.679
Intensity of cropping (percentage)	0.007	0.025	0.018	0.297	0.767	1.515
REY difference ((t ha^{-1})	0.013	0.519	0.001	0.026	0.979	1.274
Perceived advantages of CA	0.849	0.330	0.137	2.577	0.011	1.131
Perceived problems in CA methods	-0.087	0.311	-0.016	-0.279	0.781	1.363
R^2	0.513					
F	14.039***					
Durbin-–Watson test	1.827					
Number of observations	215					

The adoption decision is influenced positively but insignificantly by the location of land, plot size, extent of irrigated land, cropping intensity, REY difference of major crops round the year, and the family head's age. The size of agricultural holding inversely and highly significantly influences the decision to allocate crop acreage to CASI practices.

The indiscriminate use of chemical fertilizers has reduced the fertility of land and, in turn, production and income. Small and marginal farming households desperate to enhance farm income to cope with their ever-escalating livelihood expenditure are eager to adopt and practise eco-friendly and yield-sustaining CASI; but large farmers have a greater scale of operations and the precautionary mindset, and they prefer to wait—though persuaded of the merits of CASI. The eagerness to adopt improved methods decreases with an increase in landholding (Chuchird, Sasaki, and Abe 2017), therefore, and the "evidence suggests that [the] productivity of Indian agriculture will rise significantly if land inequality is reduced in favour of lower size holdings" (Chand 2017).

Farming households have 8–9 years of schooling on average; an extra year of schooling may improve adoption by 0.77%, a significant increase ($p = 1.6$). Several researchers argue that farming practices improve if even one member of a family has a high number of schooling years (Basu and Foster 1998; Foster and Rosenzweig 1996; Rao et al. 2017; Weir 1999). If the decision-making head is educated, they can think and act rationally. And prior awareness of CA favourably influences adoption.

We tried to resolve the research question with a three-scaled answer and by assigning the reasonable score accordingly (3 for "very good knowledge", 2 for "medium knowledge", and 1 for "poor knowledge"). We applied the concept of dummy variables to explore the reasonable answer, following Montgomery and Peck (1982). Assuming poor knowledge (1) as the dummy, the result of multiple regression shows that very good knowledge of CA could significantly increase ($p = 3.0$) adoption, by 9.94%. However, a prerequisite for maintaining the momentum of outscaling is awareness-building and the continual refreshing of the knowledge of practising farmers, as revealed also by the farmers' perception of the merits of CA.

We listed the benefits of CA and asked the respondents to respond 3 for "fully agree", 2 for "partially agree", 1 for "no idea", and 0 for "do not agree at all". A respondent's aggregate score for all the benefits constitutes the data for the explanatory variable. The perception that CA is advantageous positively and significantly ($p = 1.1$) influences the probability of adoption, by 0.85%. The perceived demerits inversely influence adoption, but the influence is insignificant—$p = 78$) (Table 8). Therefore, it is important that the machinery is operated efficiently and trials are conducted successfully.

Members of farming families visit local farmers' clubs, extension officers' offices, and banking institutions. Does the frequency of these visits influence adoption? To answer this question, we obtained three-scaled answers: 2 for "frequently", 1 for "intermittently", and 0 for "not at all". Visiting these institutions improves knowledge, rational thinking, and effective decision-making (Reddy 2003; Sreedevi 2003), and frequent visits significantly increase adoption ($p < 1.0$), in terms of allocation of acreage, by more than 10%. But the farmers have little time or inclination to visit, though their reluctance is receding slowly.

Conservation agriculture needs machinery—such as zero till seed drill, multi-crop planter, and tractors (two- or four-wheel)—and resources, like human labour, repairing units, and spare parts. Nongovernmental organizations, farmers' clubs, self-help groups, and medium or large landholders own these resources and provide these services; but the farming households in our study areas can access none of this nearby. Farmers in West Bengal have little capacity to invest in mechanization, and the progress of farm mechanization is poor (Tewari et al. 2012)—impeding the adoption of CASI.

Does proximity to resources influence adoption? We culled the data using 4 scaled answers: 3 for "available within 1 km", 2 for "available within 1–2 km", 1 for "available within 2–5 km", and 0 for "available beyond 5 km". We take "available within 5 km" as the dummy; adoption is influenced significantly highly ($p < 1.0$) within 1 km and within 1–2 km (Table 8). If the resources are available within 1 km, adoption is 24% higher than if the resources are over 5 km away; and adoption is 13% higher if the resources are within 1–2 km and 5% if 2–5 km. Therefore, adoption increases if the resources required are available within 5 km of a farmer's residence or cultivable cropland, and reliability and payment is best if the resources are available within 1 km. Providing and receiving services within a minimal distance helps both parties maintain a mutually beneficial relationship. Public extension services have declined gradually in this part of North Bengal in recent years, and the importance of groups that provide these services is increasing.

Throughout the South Asian region, women account for about 39% of the agricultural workforce. The importance of women in the daily life of a farm family, especially in developing countries, is unquestionable (Tsegaye et al. 2012); they work in a variety of roles, from agricultural labourers to land managers, and their role is expanding to include decision-making, especially in farm management. Women of families that cultivate small to medium farms work on their own farms; they seek wage employment elsewhere only if compelled to (Saikia 1999). Women are thought to influence the adoption of CA; therefore, we include women as a possible determinant in the regression analysis. We identified women's participation in farming using three-scaled data: 2 for "full participation", 1 for "partial participation", and 0 for "no participation". We estimated women's participation by the hours they spent in farming activities every day on average.

Adoption is influenced significantly by both the nature and extent of participation. We take "no participation" as the dummy. Compared to the dummy, full participation increases adoption by 5.83% ($p = 8.5$); if women increase participation by an hour, adoption may increase by 2.28% (Table 8). Therefore, women are no longer passive participants in farming; rather, their role is critical. Their direct participation and observations in the demonstration trials strengthen the understanding and, ultimately, the decision-making.

Adoption is not significantly influenced by the other assumed explanatory variables: age of the decision-making head, extent of medium to high cultivable land, extent of irrigated land, intensity of cropping, or REY difference (between CA and CT system) of year-round crops. Farm size significantly ($p < 1.0$) and inversely influences adoption; therefore, CA methods should be disseminated only to farmers who own marginal farms (< 1.0 ha), small (1–2 ha), and semi-medium farms (2–4 ha). The size of individual plots directly, though insignificantly, influences adoption, however (Table 8).

Conclusions

The SRFSI project endeavoured to transform the farming system in the Coochbehar district of West Bengal from conventional to one based on CASI. The project successfully demonstrated the potential of CASI to enhance net income and the standard of living with less investment; solve the labour crisis, especially during the peak period; and restore the degraded soil health. The demonstration oriented the farming community towards adopting CASI.

The crop acreage allocated to kharif paddy (aman) in Coochbehar district is 2.17 million ha. If CASI is practised on 10% of the area (217,000 ha), the aggregate net farm income may increase by INR 224.2 million (USD 3.03 million), according to a prima facie estimate based on a 'what if' economic analysis of SRFSI project data. We need to tap this potential.

Farm mechanization is low in West Bengal (Ministry of Agriculture nd; Tewari et al. 2012) because the investment capacity of the farming community is marginal. The state government has been implementing schemes to financially support farm mechanization, including machinery for CASI. The government has also been involving farmers' groups. But the progress has been slow; and proper monitoring and evaluation is needed to make these schemes fruitful.

Farmers will adopt CASI, and it will succeed, if the important inputs—machinery, implements, fertilizers, herbicides, insecticides, and pesticides—are made available timely at their doorstep. Therefore, the local service provider must be close by to provide the community reliable, trustworthy, and frequent monitoring and advice.

Adoption is influenced by prior knowledge or perceived awareness of the benefits of CASI on economics, soil health, and the environment; continual, concerted efforts are required in conducting participatory demonstrations at critical locations and exposure visits by farmers' groups. Exposure visits, and other methods of extension communication, let farmers observe CA crops, interact with fellow farmers, and make up their own mind. Almost every household in the study area owns a smartphone; therefore, information can be disseminated through WhatsApp groups.

Public–private partnerships, and the knowledge and confidence of local service providers, are critical in popularizing CASI in the region, and the approach centres on farmers' associations. But member farmers' committees and farmer producer organizations are not fully aware or persuaded of the technology, the parts or calibrating mechanism of the machinery, or crop protocol; and they do not have enough efficient or skilled staff. Therefore, local service providers cannot monitor effectively, a critical factor of success. And if their knowledge and skills are not refreshed regularly, their entrepreneurial skill may suffer and impede adoption.

Women's participation and decision-making in farming has improved; it influences adoption significantly and, in all probability, improves their household's farming practices. The potential must be tapped by moulding heavy farm implements into lighter, women-friendly ones and assuring women's participation in extension activities.

Whom should CASI target? The study suggests that households with small farms (1–2 ha) should be targeted first, because most adopt CASI, and then bigger plots, for the operational ease of machinery.

Better education, or a larger number of schooling years, is important in the decision to adopt CASI; therefore, the education of a farm family should be stressed upon. Decision-making is increasingly being made by the entire household, rather than by an individual, and the overall family education matters most in the changing context of decision-making at our study sites.

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