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RESEARCH ARTICLE

Adoptability and profitability of Conservation Agriculture based Sustainable Intensification (CASI) technology in paddy by the farmers in Bihar

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Abstract

Although conservation agriculture practices have been used and promoted for over a decade, farmers have only recently truly embraced and adopted the technologies. The study was conducted on 160 farmers in Bihar using multistage sampling technique with the primary objective of examining the level of technology adoption and comparing the profitability of conservation agriculture using Commission for Agricultural Costs and Prices (CACP) Cost Concept. Garrett Ranking technique was used for the study of constraints in adoption of Conservation Agriculture based Sustainable Intensification (CASI) technology. Adoption of conservation agriculture is still in its infancy in Bihar. As of late, zero tillage and conservation agriculture have been implemented on wide areas. Conservation agriculture technology was found to be embraced by roughly 39 per cent of farmers, with marginal and small farmers having the lowest adoption rates, followed by semi-medium farmers. For every rupee spent in paddy, adopters of conservation agriculture typically made 52 paisa more than conventional farmers due to decreased explicit cultivation costs (hired labour, irrigation, seeds, etc.). Comparing conservation agricultural technique to traditional cultivation methods, the average total costs in paddy decreased by 18.42 %. The major constraints reported by farmers in adoption of CASI include high weed emergence and untimely ZT (Zero Tillage) machine service provision. The implementation of conservation agriculture technology has the potential to improve living standards by reducing cultivation expenses and increasing net revenue for farmers.

Keywords: adoption; Bihar; CASI; conservation agriculture; paddy; profitability

Introduction

Over 450 million people in the Eastern Indo Gangetic Plains (EGP) of India, Bangladesh and Nepal depend on 14.43 million (M) hectares of rice-based cropping systems for their livelihoods, employment and income (1). The region has the highest concentration of rural poverty in the world (2). The biggest challenge facing agriculture today is how to sustainably produce more food with the limited resources, especially land and water, as South Asia's food production is predicted to triple by 2050 (3). A replacement method that produces more at a lower cost must be developed in order to boost farm sustainability and profitability (4). A combination of cutting-edge technology that provide sustainability, profitability and conservation agriculture more consideration is needed in agricultural systems to establish sustainable production systems. Since conventional tillage (CT) requires 4-6 tillage operations for field preparation and planting, it leads to higher production costs and a lower benefit-cost ratio when compared to conservation tillage (4, 5). To combat global warming and boost production and profitability, farmers in the area are implementing conservation agriculture for sustainable intensification (CASI) (6). Despite the region's enormous potential, the adoption rate is unimpressive (5). However, Conventional Technology continues to be the primary method of production for these crops. Due to their low input-use efficiency and high resource consumption (labour, water, electricity and biocide), the procedures are less cost-effective and unsustainable. Rice is established using the conventional method of puddling and transplanting (PTR) and rice fields are kept wet for most of the growing season (7). Additionally, frequent puddling causes shallow hard pans by upsetting the soil's structure and releasing a large amount of methane (CH_4), one of the primary greenhouse gases (GHGs) that cause global warming (8). Direct Seeded Rice (DSR) technique could be the best alternative of the conventional method of puddling and transplanting, resolving the issue of greenhouse gases release as the technique avoids the puddling of the field.

For the cultivation of rice, the majority of farmers in Bihar rely significantly on rainfall. Therefore, delays in rice transplanting are often caused by climate variability (unpredictability of rainfall), which in turn results in lower rice yields and later planting of the next wheat crop (9). Furthermore, the conventional way of planting rice increases production costs and decreases farm revenues (10). The goal of the current study is to compare the production of paddy using CASI technology with conventional farming techniques. In many districts of Bihar, including Bhojpur, Begusarai, Purnea, Samastipur,Vashali etc., a number of Conservation Agriculture (CA) technology are in practice. However, there is dearth of systematic documentation on the technology dissemination and adoption at farmers' field. An attempt has been made by different public and private organizations to intensify the overall productivity of Rice-Wheat cropping system in Eastern Gangetic Plains (EGP). Hence, one proven CASI technologies i.e. Dry Direct Seeded Rice (DSR) from different technologies, have been considered for the study. Since, the adoption of technology has pre-requisite of extending input, technical and incentive support at earlier stage of dissemination at farmers field, therefore, Purnea district of Bihar state was purposively chosen for the present study. The Purnea district of Bihar was chosen for this study because it was already implementing CASI technology interventions and farmers were gradually implementing this technology in their fields.

Materials and Methods

Purnia district covers 3202.31 km^2 area of the state of Bihar and is bordered by Araria district in north, Katihar and Bhagalpur district in South, Madhepura and Saharsa district in the west and West Dinajpur district of West Bengal and Kishanganj district of Bihar in east. The district is situated between 25^0 13' 80'' seconds and 27^0 7' 59''N latitude and between 86^0 59' 6'' and 87^0 52' 35''E longitude. Agriculture employs approximately 81 % of the workforce and generates 42 % of the state's GDP. However, in Bihar, agriculture continues to be the predominant occupation. The cropping pattern, nearly remained unchanged over the years, revealing the area is primarily a cereal economy, with more than 85 percent of its gross cropped area under cereals. Rice, wheat, legumes, potatoes, corn, sugarcane, oil seeds, tobacco and jute are the principal crops grown. The cropping intensity of the district is 102 % as compared to the state's cropping Intensity of 144 % indicating the existence of fallow land in the region. Despite having an abundance of groundwater, sufficient rainfall and healthy soil, Bihar has one of the lowest rates of agricultural productivity in all of India (11). Data was gathered from 160 sampled farmers in the Purnea East and Kasba blocks of Purnea district, Bihar, using multistage sampling technique and a pre-tested schedule (Fig. 1). The CACP Cost Concept was used to study the cost and return of paddy under conventional method and CASI Technology and Garrett Ranking Technique was used to study the factors affecting adoption of CASI Technology by the

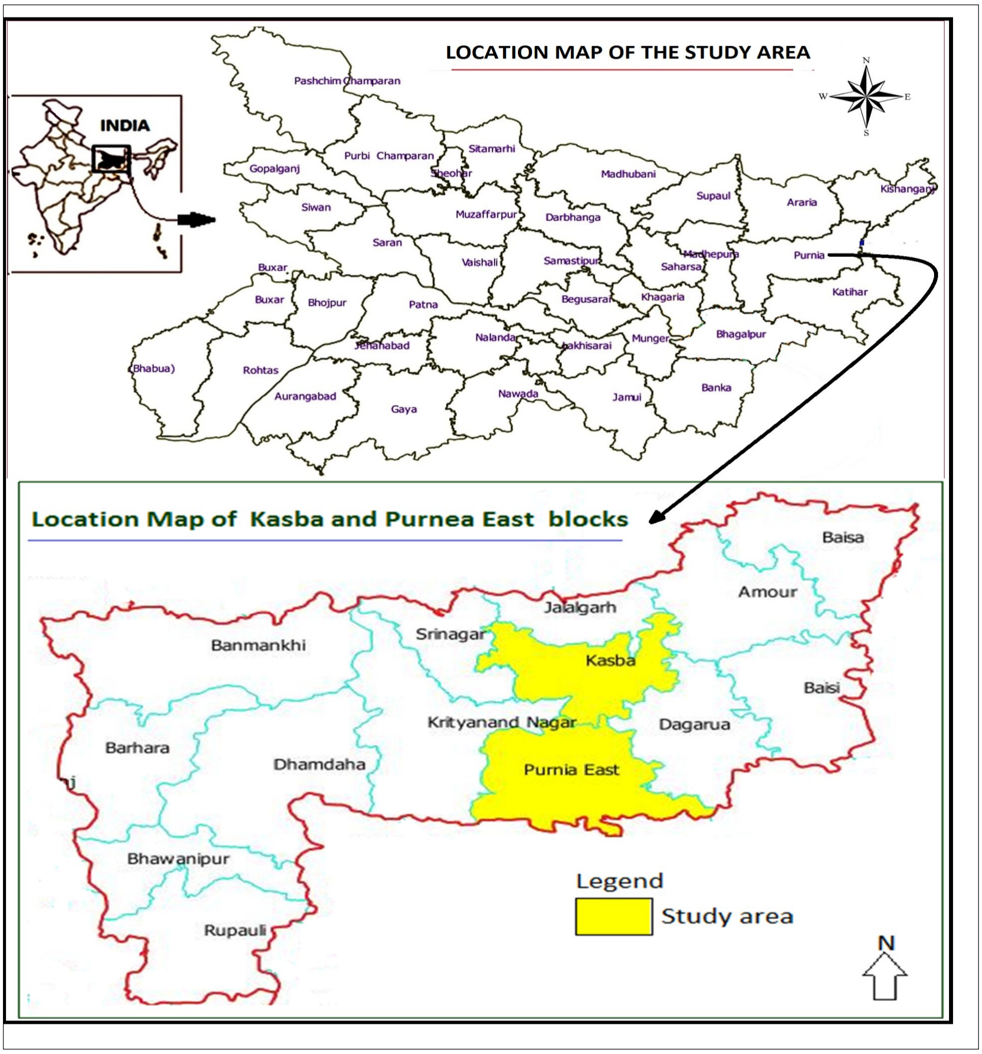

Fig. 1. Location map of the study area.

farmers in the study area. The detail of the CACP Cost Concept and Garrett Ranking Technique are given below:

(a) CACP cost concept

For the comparison of profitability of paddy grown through CASI technology vis-à-vis conventional agricultural practice, the methodology recommended by CACP has been employed.

Cost A_1 = Value of hired human labour, owned machinery labour, hired machinery charges, seeds (both farm produced & purchased), plant protection chemicals, manures (owned & purchased), fertilizers, depreciation on implements and farm buildings, irrigation charges, taxes (land revenue, cess & other) and interest on working capital

Cost A_2 = Cost A_1+ rent paid for leased in land.

Cost B_1 = Cost A_1+ interest on value of fixed capital excluding land.

Cost B_2 = Cost B_1+ rental value of owned land (net of land revenue) + rent paid for leased in land.

Cost C_1 = Cost B_1+ imputed value of family labour.

Cost C_2 = Cost B_2+ imputed value of family labour.

Cost C_3 = Cost C_2+ value of management input at 10 % of total cost (Cost C_2)

(b) Garrett's ranking technique

The Garrett's Ranking Technique was used to compute the important constraints encountered by the farmers in the adoption of CASI technology. Farmers were asked to rank the problems based on severity of the problem mentioned in the schedule that help to know the factors limiting the adoption of the technology at the farm. The order provided by the respondents was converted into per cent position using the formula mentioned below. Accordingly, the per cent position of each rank was converted to scores by referring to tables given by (12).

In the first stage, rank given to different attributes by each respondent were converted into per cent position value by using the formula:

$$\text{Per cent Position} = 100*(R_{ij} - 0.50)/N_j$$

Where, R_{ij}- Rank given for i^{th} item by j^{th} individual

N_j-Number of items ranked by j^{th} individual

In the next stage, each per cent position were converted to Garrett by referring to Garrett's tables. In third stage, summation of these scores for each factor was worked out for the number of respondents who ranked for each factor. Further, mean scores were calculated by dividing the total scores by the number of respondents. At the last stage, overall ranking was obtained by assigning ranks such as 1, 2, 3… etc. in the descending order of the mean score. The mean score for all the factors were ranked, following the decision criterion that higher the value, the more important is the order of preferences by the respondents.

Results and Discussion

The sample farmers of the study region were classified into three classes i.e. marginal and small, semi-medium and medium farmers based on their size of operational land holding size. Of the 160 farmers that responded, 58 were marginal or small farmers (36.25 %), 57 were semi-medium farmers (35.62 %) and 45 were medium farmers (28.13 %). Table 1 indicates the classification of farmers based on their operational land holding size. The marginal and small farmers dominated the research area, followed by semi-medium and medium-sized farmers that aligns with Bihar's agrarian structure, where over 85 % of farmers are marginal or smallholders (13). The study found that landholding size significantly influenced technology adoption behaviour. Medium farmers, with relatively more resources, were more open to experimenting with new technologies, as they could better absorb risks and potential losses (14). In contrast, marginal and small farmers exhibited risk-averse behaviour, often preferring stable income-generating crops like maize. These farmers expressed hesitation toward adopting new technologies unless their benefits were well-demonstrated and perceived as low risk, aligning with Rogers' diffusion of innovation theory (15).

The extent and status of adoption of CASI technology among the sample farmers have been depicted in Table 2. The findings revealed that 63 farmers (39.38 %) had implemented CASI technology, whereas 97 farmers (60.63 %) were still undecided about implementing CASI technology in their farm. These findings aligned with the previous observations (16, 17), whereby it was found that the adoption rate of technology increases with the increase in land holding size of the farmers. It could be inferred that the diffusion of any technology which is profitable and easy to use progressively gains prominence. The

Table 1. Classification of sample farmers based on their size of operational holding

Farmer category	Kasba (n_1=80)	Purnea East (n_2=80)	Overall farmers (N=160)
Marginal and small farmers (≤5 acre)	27 (33.75)	31 (38.75)	58 (36.25)
Semi-medium farmers (>5 to 10 acre)	30 (37.50)	27 (33.75)	57 (35.62)
Medium farmers (>10 acre)	23 (28.75)	22 (27.50)	45 (28.13)
Total	**80 (100.00)**	**80 (100.00)**	**160 (100.00)**

Note: Figures in parenthesis indicates percentage to total

Table 2. Extent of CASI adoption among different categories of farmers

Farmer's Category	CASI Adopter farmers	CASI Non- Adopter farmers	Overall farmers
Marginal and small farmer	11 (6.88)	47 (29.38)	**58 (36.25)**
Semi-medium farmer	23 (14.38)	34 (21.25)	**57 (35.63)**
Medium farmer	29 (18.13)	16 (10.00)	**45 (28.13)**
Total	**63 (39.38)**	**97 (60.63)**	**160 (100.00)**

Note: Figures in parenthesis indicates percentage to total respondent farmers believed that conservation agriculture adoption had steadily increased over time and the adopters (39.38 %) were satisfied with their decision to adopt it. Additionally, they reported that the majority of other farmers (60.63 %) who continued to use traditional methods were trying to switch to sustainable practices after witnessing increased returns from the time and money they had saved. The adoption of CASI technology was lowest among marginal and small farmers (6.88 %) because they were mostly risk averse and only produced for their own consumption. In order to cut expenses, they attempted to maximise family labour, which would not be feasible with CASI. Likewise, they were reluctant to explore with their modest holding size. Moreover, factors that might contribute to non-adoption include field position, timely availability of Zero Till (ZT) machines, etc.

Table 3 depicts the cost and return of paddy cultivation using the conventional method. It has been found that the average total variable cost incurred by all farmers was Rs. 33084 per acre, which constituted 96.77 percent of the average total cost (Rs. 34188 per acre) and the average total fixed cost was Rs. 1104 per acre, accounting for 3.23 percent of the average total cost. The average gross return per acre was Rs. 39610, with a net income of Rs. 5422 and a return to cost ratio of 1.16. Land preparation (7.12 %), seed (6.50 %), plant protection chemicals (2.12 %), manures and fertilizers (12.36 %), irrigation (12.55 %), hired human labour (29.05 %) and harvesting, transportation, threshing and storage (17.28 %) were the cost components with the highest expenses. Labour-intensive operations significantly influenced overall costs, with seasonal shortages during peak periods contributing to high labour expenses (18, 19). The high irrigation cost was linked to increased water demand during critical crop growth stages, consistent with findings by Das and Mishra (20). Additionally, bulk and non-selective use of fertilizers-primarily due to farmers' limited knowledge about scientific application-further escalated production costs. Poor access to extension services often leads smallholders to rely on traditional practices such as fertilizer broadcasting, reducing nutrient use efficiency and increasing costs (21). Return-to-cost ratios varied slightly among farmer categories, ranging from 1.17 to 1.21, indicating modest profitability.

Table 4 illustrates that the average total cost of cultivation for paddy using Direct Seeded Rice (DSR) technology was ₹27889 per acre, of which the total variable cost constituted ₹27144 per acre (96.77 %), while fixed costs were minimal at ₹745 per acre (2.67 %). The gross return realized from DSR was ₹46808 per acre, resulting in a net income of ₹18,919 and a return-to-cost ratio of 1.68, indicating a reasonably lucrative enterprise. A breakdown of the cost components shows that the highest expenditures were associated with post-harvest operations such as harvesting, transportation, threshing and storage (22.44 %), followed by hired human labour (19.55 %), manures and fertilizers (14.85 %), irrigation (11.82 %), plant protection chemicals (7.94 %), seed (6.90 %) and land preparation (4.69 %). The result is in line with the findings of Chaudhary et al., who emphasized that DSR dramatically lowers labour, water and energy inputs, resulting in a cheaper cultivation cost when compared to conventional methods (22). Sapkota et al. highlighted that DSR results in significant labour reductions in irrigation and hand transplanting, two of PTR's most expensive procedures (23). From previous studies similar results, pointing out that the technology not only lowers input prices but also improves operating efficiency, which raises profitability (24).

Table 3. Cost and return of paddy cultivation across different categories of farmers through Conventional method (Rupees/acre)

Particulars	Category of farmers			
	Marginal and small farmers (n_1=47)	**Semi-medium farmers (n_2=34)**	**Medium farmers (n_3=16)**	**Overall farmers (N=97)**
A. Variable Cost				
Land preparation	2352	2489	3044	2434
Seed	2192	2241	2463	2222
Plant Protection Chemicals	713	735	806	725
Manures and Fertilizer	4156	4259	4839	4224
Irrigation	4261	4321	4383	4289
Harvesting, transportation, threshing and storage	5846	5945	6413	5908
Labour Cost	9078	10828	13431	9933
Rent paid for leased in land	2171	2042	1250	2082
Miscellaneous charges	265	343	443	303
Interest on working capital @12 % p.a.	931	996	1112	964
Total Variable Cost (A)	31964	34198	38184	33084
B. Fixed Cost				
Land Revenue	54	54	54	54
Depreciation	466	531	935	949
Interest on fixed cost @ 10 % p.a.	52	58	99	100
Total Fixed Cost (B)	572	643	1088	1104
Total Cost (C)	32536	34841	39272	34188
D. Gross Income				
Paddy Grain	34928	37883	43813	36438
Paddy Straw	3008	3344	3838	3172
Gross Income	37936	41227	47650	39610
E. Net Income (D-C)	5400	6386	8378	5422
F. Return to Cost Ratio (D/C)	**1.17**	**1.18**	**1.21**	**1.16**

Table 4. Cost and returns of paddy cultivation across different categories of farmers using DSR technology (Rupees/acre)

Particulars	Category of farmers			Overall farmers (N=63)
	Marginal and small farmers (n1=11)	Semi-medium farmers (n2=23)	Medium farmers (n3=29)	
A. Variable Cost				
Land preparation	1154	1310	1377	1309
Seed	1724	1919	2020	1925
Plant Protection Chemicals	2184	2196	2241	2214
Manures and Fertilizer	4038	4112	4214	4142
Irrigation	3146	3257	3397	3297
Harvesting, transportation, threshing and storage	5583	5941	7023	6258
Labour Cost	3886	5394	5711	5451
Rent paid for leased in land	1853	1539	1053	1386
Miscellaneous charges	272	344	440	372
Interest on working capital @12 % p.a.	715	780	824	791
Total Variable Cost (A)	24556	26792	28299	27144
B. Fixed Cost				
Land Revenue	52	52	52	52
Depreciation	498	702	824	625
Interest on fixed cost @ 10 % p.a.	55	75	88	68
Total Fixed Cost (B)	605	830	964	745
Total Cost (C)	25161	27622	29263	27889
D. Gross Income				
Paddy Grain	36810	40223	48182	43065
Paddy Straw	3402	3719	3916	3743
Gross Income	40212	43942	52098	46808
E. Net Income (D-C)	15051	16320	22835	18919
F. Return to Cost Ratio (D/C)	1.60	1.59	1.78	1.68

Table 5 presents a comparative analysis of the profitability of paddy cultivation under conventional and DSR systems. The findings reveal that adoption of CASI practices significantly enhanced economic efficiency. DSR adopters observed an 18.17 % rise in gross income and an 18.42 % decrease in total production costs when compared to their conventional counterparts. Reduced spending on variable inputs, such as labour (-45.12 %), seeds (-13.38 %), irrigation (-23.13 %) and land preparation (-46.24 %), was the main cause of the overall cost decrease, which resulted in a 17.95 % decrease in total variable expenses. These results are consistent with those of Ghosh et al., who documented comparable increases in resource-conserving technology efficiency (25). However, DSR adopters saw a 205.24 % increase in the cost of plant protection chemicals, probably due to changed pest dynamics brought about by the new practices (26). Effective nutrient usage demonstrated by the marginal 1.94 % decrease in manure and fertilizer prices. In terms of profitability, DSR farmers made 52 paisa more for every rupee invested, which is a 44.86 % increase over the traditional approach. Additionally, more than 90 % of medium-sized farmers used CASI procedures on at least some of their

Table 5. Comparison of profitability of paddy cultivation between conventional and CASI adopter farmers (Rupees/acre)

Particulars	CASI Non-Adopter farmers (n1=97)	CASI Adopter farmers (n2=63)	Changes due to adoption (+/-)	% change in cost due to CASI adoption
A. Variable Cost				
Land preparation	2434	1309	-1126	-46.24
Seed	2222	1925	-297	-13.38
Plant Protection Chemicals	725	2214	1489	205.24
Manures and Fertilizer	4224	4142	-82	-1.94
Irrigation	4289	3297	-992	-23.13
Harvesting, transportation, threshing and storage	5908	6258	350	5.92
Labour Cost	9933	5451	-4482	-45.12
Rent paid for leased in land	2082	1386	-696	-33.43
Miscellaneous charges	303	372	70	22.99
Interest on working capital @ 12 % p.a.	964	791	-173	-17.95
Total Variable Cost (A)	33084	27144	-5940	-17.95
B. Fixed Cost				
Land Revenue	54	52	-2	-3.70
Depreciation	949	625	-324	-34.15
Interest on fixed cost @ 10 % p.a.	100	68	-33	-32.51
Total Fixed Cost (B)	1104	745	-359	-32.51
Total Cost (C)	34188	27889	-6299	-18.42
D. Gross Income				
Paddy Grain	36438	43065	6627	18.19
Paddy Straw	3172	3743	571	18.00
Gross Income	39610	46808	7198	18.17
E. Net Income (D-C)	5422	18919	13497	248.94
F. Return to Cost Ratio (D/C)	**1.16**	**1.68**	**0.52**	**44.86**

property, showing a strong association between CASI adoption and farm size. Their better access to finance, increased ability to control risk and willingness to try new things through trial and error are the reasons behind this development (27).

Higher weed infestation was the main obstacle, particularly in Direct Seeded Rice (DSR) fields, where farmers' Garrett scores ranged from 72.15 to 72.56 (Table 6). This difficulty is in line with previous studies and who pointed out that because of the decreased soil disturbance in CASI systems, weed control remains a persistent problem (28, 29). With Garrett scores ranging from 69.73 to 66.88 across farmer categories, the second most urgent limitation was the delayed availability of Zero Tillage (ZT) equipment. ZT service delay interferes with the best times to sow, which lowers DSR's efficacy. For marginal and small farmers (67.55) and medium farmers (61.28), uneven germination of seedlings with ZT sowing was the third most important problem, while for semi-medium farmers, it came at number four. Another significant obstacle was the ZT machinery's subpar performance, which led to unequal seed placement. It came in third place for semi-medium farmers and fourth for marginal, small and medium farmers. The earlier studies also reported that CASI adoption is adversely impacted by insufficient machinery services and restricted access to dependable equipment (30). Risk aversion towards unpuddled rice farming, doubts regarding the effectiveness of CASI, inadequate extension services and land fragmentation-which disproportionately affects smallholders were other noteworthy obstacles. Adoption was further limited by cultural hostility, unstable land tenure and a lack of qualified service providers.

Conclusion

The research unequivocally shows that farm size has a major impact on the uptake of DSR and other CASI technologies. Despite its proven benefits, DSR adoption remains lowest among marginal and small farmers, primarily due to risk aversion, limited financial capacity and lack of timely access to equipment and advisory services. whereas medium and semi-medium farmers shown a greater willingness and capacity to implement such advances. Adoption of DSR confirmed its economic viability by resulting in a significant increase in profitability (44.86 %) and a notable decrease in production costs (-18.42 %) compared to conventional methods. Broader diffusion is still hampered, nevertheless, by important adoption barriers such increased weed infestation, delayed availability to Zero Tillage equipment and inconsistent seed germination. DSR technology (CASI) appears as a viable and scalable solution to increase production sustainably within current holdings, given the limitations on growing cultivable land either horizontally or vertically. A number of calculated actions are required to encourage smallholders to use CASI technology more widely. To ensure that equipment like Zero Till drills are available on time, it is essential to improve access to Custom Hiring Centres (CHCs). Farmers' confidence can be increased by bolstering extension services with training, field demonstrations and information in their native tongue. To lessen hesitancy, incentive-based solutions that offer input subsidies and risk coverage for new users ought to be encouraged. By bridging the adoption gap and improving smallholder income, resilience and sustainability, these combined efforts will make CASI a workable solution for the tiny and dispersed farming systems in Bihar.

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Authors' contributions

NK carried out the research work. MKW major advisor of the first author and conceived the idea of the research work. SMR co-advisor of the first author and assisted in data analysis. MK helped in the preparation of the manuscript. AK[1] assisted in carrying out survey and data analysis. AK[2] helped in preparation of manuscript. SLB helped in carrying out the survey and preparation of manuscript. SK assisted in the manuscript preparation (AK[1]- Alpana Kusum, AK[2]- Avinash Kumar). All authors read and approved the manuscript.

Table 6. Constraints faced by the farmers in adoption of CASI technology

Sl. No.	Constraints	Marginal and small farmers		Semi-medium farmers		Medium farmers	
		Garrett's score	Rank	Garrett's score	Rank	Garrett's score	Rank
1	High weed emergence with CASI technology at the farm	72.56	I	72.87	I	71.15	I
2	Untimely ZT machine service provision	69.67	II	69.73	II	66.88	II
3	Uneven germination of seedlings with ZT machine	67.55	III	53.69	IV	61.28	III
4	Poor Machine performance such as uneven sowing of seeds	60.21	IV	64.04	III	58.45	IV
5	Sceptic and risk aversion of farmers for unpuddled rice technology	57.34	V	50.77	V	52.09	V
6	Poor extension services and awareness of technology	51.89	VII	38.68	VIII	47.99	VI
7	Fragmented as well as small operational land size and diversified cropping patterns	46.68	VI	47.46	VI	41.17	VII
8	Insufficient incentives associated with farm tenure arrangements	39.97	VIII	41.45	VII	39.14	VIII
9	Cultural norms and negative opinions of the neighbouring farmers	33.23	X	28.31	X	31.68	IX
10	Dearth of trained and efficient technology service providers	29.47	IX	30.32	IX	27.56	X

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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