Can farm mechanization enhance small farmers' income? Lessons from Lower Shivalik Hills of the Indian Himalayan Region

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Indian agriculture being fraught with fragmented land holdings, the economic viability of farm mechanization has forever remained a debatable issue. Here we determine the socio-agro-economic impact of seed-cum-fertilizer drill and zero tillage through different methods with ex-ante and ex-post approaches. Results depict that labour costs had reduced by almost 80% and seed usage by 20%. The seed-cum-fertilizer drill and zero tillage adopter saved Rs 3764.10 and 4047.54 respectively, from 1 ha. The machinery also increased the yield of HD 2967 wheat variety by 13.39 and 6.0 q/ha, and decreased seed rate by 27.71 and 24.20 kg/ha respectively, as evident from the results of the SUR model. The growth of the farm machinery sector is hindered by machine cost, resource-poor farmers and inaccessibility of agricultural technology. A few suggestions on the critical aspects are made here based on the application of technology in different states of India to implement suitable policies for the economic benefit of farmers.

Keywords: Efficacy measure, farm mechanization, labour cost, socio-agro-economic impact, synchronous bootstrapping.

WITH a population of 1.4 billion, India has about 118 million farmers and 144 million agricultural labourers. About 54.6% of the total workforce has contributed to the country's self-sufficiency in food and nutritional security[1]. The Green Revolution has contributed to the overall achievement in agricultural production and productivity through the dissemination of technology and farm mechanization. It is estimated that farm mechanization reduced the cost of seeds and fertilizers by 15%, animal labour by 60% and human labour by 20%. In wheat crop, automation resulted in a yield gain of 10% and a reduction in the cost of up to 25% for seeds, 30% for irrigation water and time saving for farm managers[2]. The predominance of small farms in India, as well as the economic and technical feasibilities of the application of machinery, give rise to pertinent constraints. Thus, there is a demand for the development of scale-specific/appropriate technologies. However, seed-cum-fertilizer drill and zero tillage (ZT) implements have been used efficiently in many small and marginal farms in India by improving the efficiency of fertilizers, water, labour, cost, time, power and avoid heat stress in wheat cultivation[3]. The present study examined the impacts of seed-cum-fertilizer drill and ZT machines on the production and productivity of improved varieties of wheat in the Lower Shivalik Hills of the Indian Himalayan region during 2016–19. The objective of the study was to evaluate the social and economic performance (yield and return) of the adoption of these implements on some improved varieties of wheat. It also explored the primary information for the use of policy-making bodies for upscaling (vertical) and outscaling (horizontal) of farm machinery to expand the area under these technologies.

Materials and methods

Study area

The region of the Lower Shivalik Range of Uttarakhand, India, has good natural resources, but recorded the lowest agricultural productivity among other States of the Lower Shivalik Hills (Figure 1). Thus, this region was selected for the present study. In view of obtaining the accuracy and desired confidence level, the Cochran formula was used to determine an optimal sample size of 380 instead of simple random sampling.

Statistical tools and software

Binary logistic regression was applied to determine the factors affecting the adoption decision of the farmers. Kendal tau was used to estimate the extent of association between different independent variables. The seeming unrelated regression (SUR) model was employed to estimate the economic efficacy of the technology (farm machinery) with respect to crop varieties. Alfares and Duffuaa's methodology was used to determine the factors for upscaling technologies, which is based on a linear rank–weight

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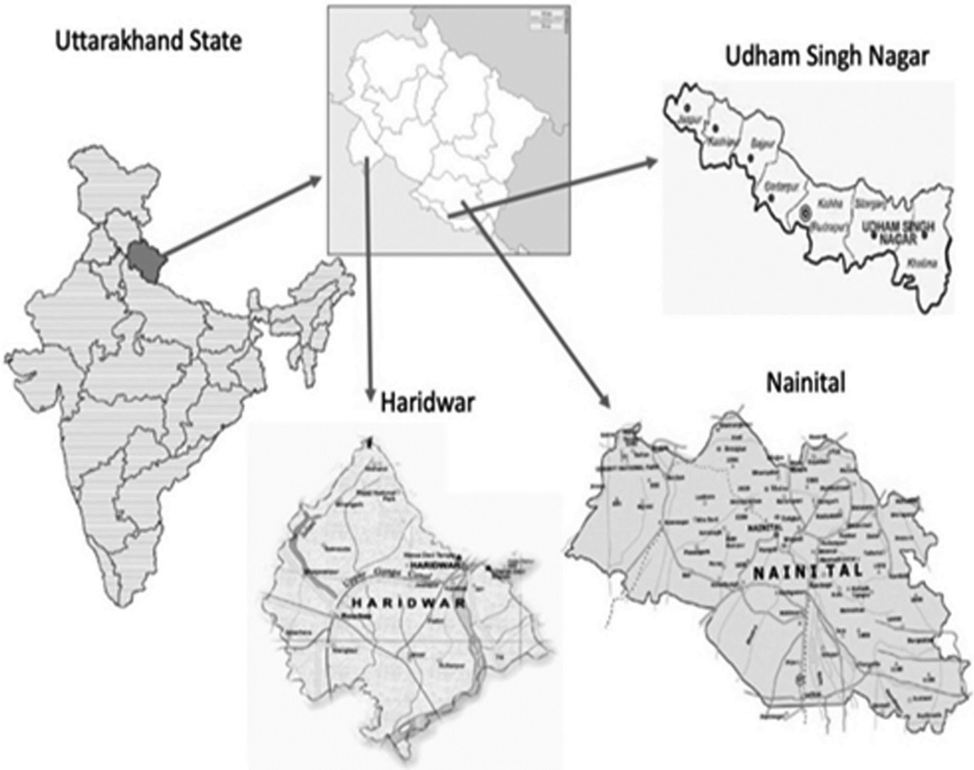

Figure 1. Location of the micro study area.

function whose slope (S_n) depends on the number of criteria (n). Garrett ranking helped trace out the most significant factor influencing the respondents and the outcomes were converted into score values. Data were analysed using SPSS V16.0, STRATA_12, R 4.0.3.

Results and discussion

Extent and determinants of adoption of farm machinery

Nearly 45% of farmers had adopted seed-cum-fertilizer drills, whereas the adoption rate was 32.78% for ZT. The reason for low levels of adoption was small-sized land holdings of farmers, their low levels of awareness about the machineries and inadequate capital to invest in machineries. Focus group discussions also revealed the same factors. The farmers needed assurance of good results like a profitable benefit-cost ratio of the machineries in their field conditions to make adoption decisions. Table 1 shows the level of adoption of the technology. Availability of information (0.00*), mass media exposure (0.02**), risk orientation (0.06***), innovativeness (0.09***) and farm asset (0.00*) were the significant factors influencing adoption. Table 2 provides estimates of the binary logistic regression for adoption. Information through mass media and risk-bearing ability enhanced the ability to make decisions for seed-cum-fertilizer drill, in alignment with aligns the results of Feder *et al.*[4]. Supporting facilities like a custom-hiring centre could play a major role in influencing the non-adopters. With every added unit of an acre of land, the chance of adoption also increased by 1.27%. Awareness had a positive impact on adoption, with the likelihood of adoption of 1.13%. Figure 2 shows the results of Kendall's Tau correlation, where the crucial independent variables were used to measure the level of determinants for adoption with seed-cum-fertilizer drill. Accessibility to information (0.45), mass media exposure (0.26), innovativeness (0.25) and farm asset (0.78) showed positive and significant roles. Farmers with more access to information and mass media exposure had greater awareness regarding the efficiency of resources which, in turn, increased income. Similar findings were also reported by Beyene and Menale[5]. In the case of ZT adoption, frequency of use (0.26) and innovativeness (0.43) played the same role.

Socio-agro-economic impact of farm machinery

Application of difference in difference (DID) method (ex-ante and ex-post) on social, agronomic and economic aspects showed that labour cost had declined by nearly 80% (9.82 to 2.80 MD (Mandays)) and savings of seed increased by 20% (151.04 to 108.65 kg/ha) for seed-cum-fertilizer drill (Table 3). Results on the adoption of ZT implements

Table 1. Extent of adoption of farm machinery (n = 360)

Farm machinery

Seed-cum-fertilizer drill (n = 360)

Adopter		Non-adopter	
f	Percentage	*f*	Percentage
161	44.72	199	55.27

Frequency distribution of adopter categorization based on Operational Land Holding (OLH)

Category	Range	Frequency	Percentage
Low	4.5–6.6	26	16.14
Medium	6.60–10.38	109	67.70
High	10.38–13	26	16.14

Zero tillage (n = 360)

Adopter		Non-adopter	
f	Percentage	*f*	Percentage
118	32.78	242	67.22

Frequency distribution of adopter categorization based on OLH

Category	Range	Frequency	Percentage
Low	6–7.42	15	12.71
Medium	7.42–10.69	83	70.33
High	10.69–13	20	16.94

Table 2. Binary logistic regression analysis for determinants of adoption

	Seed-cum-fertilizer drill			Zero tillage		
Independent variables	LR chi2(19): 450.44, Prob > chi2: 0, Pseudo R2: 0.9099, log likelihood = –22.303804			LR chi2(18): 171.48, Prob > chi2: 0, Pseudo R2: 0.37, log likelihood = 141.99		
Explanatory variables	Odds ratio	*Z*	*P* > *z*	Odds ratio	*Z*	*P* > *z*
Operational land holding	1.37	1.20	0.22	1.27	2.55	0.01*
Age	0.93	–1.25	0.21	0.98	–1.05	0.29
Educational status	1.26	0.45	0.65	1.07	0.47	0.636
Family type	0.21	–0.95	0.34	0.94	–0.13	0.893
Extension contact	0.87	–0.79	0.42	1.08	1.26	0.209
Extension activity	0.62	–1.55	0.12	1.11	0.99	0.323
Availability of information	5.15	3.82	0.00*	1.06	0.37	0.713
Marital status	0.52	–0.55	0.58	0.59	–1.19	0.235
MME	2.02	2.26	0.02**	1.15	1.62	0.106
Frequency of use	1.28	1.26	0.20	1.13	2.35	0.01*
Risk orientation	0.76	–1.88	0.06***	1.04	1.02	0.30
Innovativeness	1.13	1.66	0.09***	1.08	2.97	0.00*
Availability of credit	2760.86	0.28	0.77	1.29	0.8	0.423
Distance from input market	2.14	0.96	0.33	1.28	1.2	0.231
Distance from output market	0.38	–1.14	0.25	0.85	–0.65	0.513
Experience in farming	1.01	0.29	0.77	0.99	–0.11	0.911
Farm asset	13.73	4.13	0.00*			
Livestock	0.26	–0.98	0.32	1.081	0.23	0.818
Possession of vehicle	2.56	1.17	0.24	2.14	–5.46	0
Constant	3.02	–1.44	0.15	2.14	–5.46	0

*Significance at 1%; **Significance at 5%; ***Significance at 10%.

were also similar. Table 3 shows the results of the adoption of seed-cum-fertilizer drills related to socio-agronomic aspects. Positive impacts of ZT technology (ex-ante and ex-post analysis) on agronomic and economic issues were prominent. Thus, the adoption of ZT helped farmers increase productivity and net return. A similar study carried out by Verma and Tamrakar[6] gave similar results.

Economic impact of seed-cum-fertilizer drill and zero tillage on the community

Comparative economic analysis between adoption and non-adoption of seed-cum-fertilizer drill in wheat production showed that yield, return and return from custom hiring were attractive for adopter farms (Table 4). The cost of

Table 3. Impact of seed cum fertilizer drill adoption on socio-agronomic aspects (DID method; $N = 360$)

Particulars	Seed-cum-fertilizer drill: Adopter (n = 161) After	Seed-cum-fertilizer drill: Adopter (n = 161) Before	Seed-cum-fertilizer drill: Adopter (n = 161)	Seed-cum-fertilizer drill: Non-adopter (n = 199)	Zero tillage: Adopter (n = 114) After	Zero tillage: Adopter (n = 114) Before	Zero tillage: Adopter (n = 114)	Zero tillage: Non-adopter (n = 246)
Field capacity (h/ha)	2.5	5.12	2.5	5.16	2.5	5.98	2.5	5.98
Seed rate (kg/ha)	108.65	151.04	108.65	150.77	100.61	138.64	100.61	138.64
Labour requirement for land preparation (MD/ha)	2.80	9.81	2.80	9.93	2.69	8.29	2.69	8.29
Germination percentage	94.81	82.80	94.81	80.98	90	80	90	80
Crop establishment (%)	90.29	79.84	90.29	74.77	90	85	90	85
Plant population per ha of area (%)	90	81.43	90	85.26	90	75	90	75
NPK application (kg/ha)	120.18	158.38	120.18	158.59	359.39	382.85	359.39	382.85

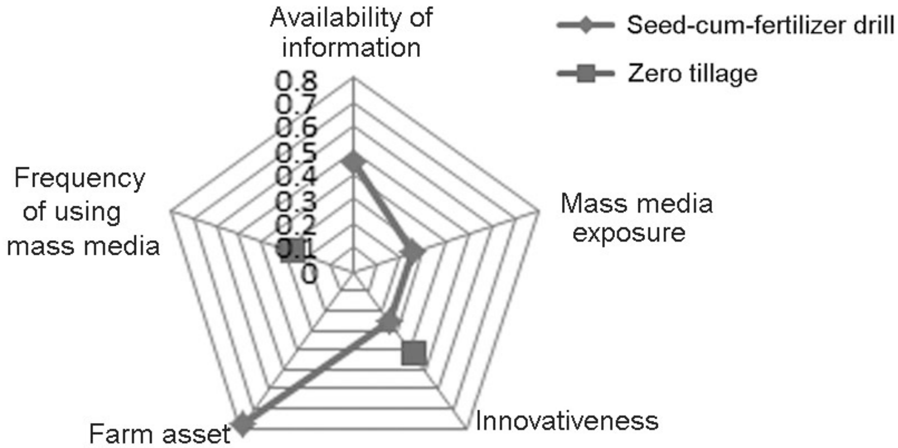

Figure 2. Kendall tau estimation between farmers using seed-cum-fertilizer drill and zero tillage (ZT), and significant explanatory variables.

sowing was also reduced. Compared to the cost of sowing, seed-cum-fertilizer drill saved an extra Rs 3764.10/ha. Values of paired *t*-test (within adopter) and independent *t*-test (between adopter and non-adopter) indicated a significant difference in sowing cost.

The net benefit over investment for adopting of ZT implements was Rs 41,384.59/year, with a very high benefit–cost ratio of 4.06 (Table 5). Comparing the cost of sowing through ZT and broadcasting, the former method saved Rs 3879.86/ha towards seed cost. Results of paired *t*-test (within adopter) as well as an independent *t*-test (between adopter and non-adopter) revealed a significant positive difference between ZT sowing adopter and non-adopter (broadcasting).

Farm-level efficiency of improved machinery for upscaling

The SUR model was used adopted to test three wheat varieties (HD-2967, HD-3086 and HD-3059). The RMSE value in the model confirmed 11.48%, 27.63% and 26.17% absolute fit of predicted results of yield estimation for the three varieties respectively, compared to the ordinal least square (OLS) method (Table 6). The model presented 24.42%, 63.31% and 64.56% more efficient absolute predicted results for seed rate estimation respectively. Low RMSE values imply a better fit. Besides, using a seed drill gave 13.39 q/ha more yield for the variety HD-2967 which was better compared to other varieties. It saved the seed rate up to 27.71 kg/ha, which was much higher than the other two varieties. Thus, HD-2967 showed better economic advantages. The yield of wheat variety HD-2967 was enhanced by 6.0 q/ha using ZT and it was much more compared to the other two selected varieties (Table 7). Adopting this technology also helped save seed rate by 24.20 kg/ha for the same variety.

Scenario building and synchronous bootstrapping towards farm mechanization

The prospect of scaling-up of improved wheat varieties in particular regions of India is presented in Figure 3, where the usage of machinery in the cultivation of these crops leads to enhanced production and productivity. Based on the secondary data, Figure 4 shows the state-wise scenario for applying seed drill and ZT technologies with reference to wheat varieties. The cost of cultivation was the lowest in Punjab and farmers could earn an additional income of Rs 13,000/ha with variety HD-2967, which was higher than the other two varieties. However, the MSP price could fetch more returns for all the farmers. In the case of ZT,

Table 4. Comparative economic analysis of seed-cum-fertilizer drill and broadcasting

Economic analysis of seed-cum-fertilizer drill and broadcasting (n = 161)				Economic analysis of seed cum fertilizer drill adopter and non-adopter (n = 360)			
Adopter category				Adopter		Non-adopter	
Farmer's own seed-cum-fertilizer drill		Broadcasting		Seed-cum-fertilizer drill		Broadcasting	
Fixed cost	Rs/year	Variable cost	Rs/ha	Fixed cost	Rs/year	Variable cost	Rs/ha
Interest cost	361.25	Seed cost (Rs/ha)	6,037.78	Interest cost	361.25	Seed cost (Rs/ha)	6,030.75
Insurance and taxes	–	Manpower cost (Rs/ha)	3,928.40	Insurance and taxes	0.00	Manpower cost (Rs/ha)	3,973.87
Depreciation cost	1.50	Expenditure on NPK (Rs/ha)	3,800	Depreciation cost	1.50	Expenditure on NPK (Rs/ha)	3,806.23
		Land preparation cost	1,980.00			Land preparation cost	1,980.00
Total fixed cost	362.75			Total fixed cost	362.75		
Variable cost		Total	15,746.17	Variable cost		Total	15,790.85
Fuel cost	285.00			Fuel cost	285.00		
Land preparation cost	1,980.00			Land preparation cost	1,980.00		
Seed cost (Rs/ha)	4,343.89			Seed cost (Rs/ha)	4,343.89		
Lubricant cost	4.25			Lubricant cost	4.25		
Manpower cost (Rs/ha)	1,121.74			Manpower cost (Rs/ha)	1,121.74		
Expenditure on NPK (Rs/ha)	2,884.44			Expenditure on NPK (Rs/ha)	2,884.44		
Maintenance cost	1,000.00			Maintenance cost	1,000.00		
Total variable cost	11,619.32			Total variable cost	11,619.32		
Total cost	11,982.07			Total cost	11,982.07		
Return from own farm	1,479.26						
Income from custom hiring	50,000						
Total income	51,479.26						
Net income	39,504.09						
Benefit cost ratio for seed drill	1 : 3.29	Paired t test	126.36***			Independent t test	62.55***

**Price of seed-cum-fertilizer drill: Rs 50,000 per unit (unit cost for investment activities in agriculture and allied sectors, Uttarakhand 2019–20). ***Significance at 1%.

Table 5. Comparative economic analysis of zero tillage (ZT) and broadcasting

Economic analysis ZT and broadcasting (n = 114)				Economic analysis of ZT adopter and non-adopter (n = 360)			
Adopter category				Adopter		Non-adopter	
Farmer's own ZT		Broadcasting		ZT		Broadcasting	
Fixed cost	Rs/year	Variable cost	Rs/ha	Fixed cost	Rs/year	Variable cost	Rs/ha
Interest cost	375.7	Seed cost (Rs/ha)	5,374.576	Interest cost	375.7	Seed cost (Rs/ha)	5,545.528
Insurance and taxes	0	Manpower cost (Rs/ha)	3,320.339	Insurance and taxes	0	Manpower cost (Rs/ha)	3,317.073
Depreciation cost	2.93	Expenditure on NPK (Rs/ha)	3,389	Depreciation cost	2.93	Expenditure on NPK (Rs/ha)	3,389
		Fuel cost	1,980			Fuel cost	1,980
Total fixed cost	378.63			Total fixed cost			
Variable cost		Total	14,063.92	Variable cost		Total	14,231.6
Fuel cost	285			Fuel cost	285		
Land preparation cost	0.00			Land preparation cost	0.00		
Seed cost (Rs/ha)	4,024.57			Seed cost (Rs/ha)	4,024.576		
Lubricant cost	4.28			Lubricant cost	4.28		
Manpower cost (Rs/ha)	1,074.58			Manpower cost (Rs/ha)	1,074.58		
Expenditure on NPK (Rs/ha))	3,417			Expenditure on NPK (Rs/ha)	3,417		
Maintenance cost	1,000			Maintenance cost	1,000		
Total variable cost	9,805.43 (23.69)			Total variable cost			
Total cost	10,184.06			Total cost	10,184.06	Independent t test: 114.50***	
Return from own farm	1,568.64						
Income from custom hiring	50,000						
Total income	51,568.64						
Net income	41,384.59						
Benefit cost ratio for ZT: 4.06		Paired t test= 30.098***					

Values in parenthesis indicate percentage of cost with respect to net income. ***Significance at 1%.

Table 6. Efficacy measurements of seed drill on wheat crop

Equation	Variety	RMSE	R^2	F	P	
Yield	HD 2967	11.48	0.169	72.85488	0.000	
	HD 3086	27.63	0.047	17.86826	0.000	
	HD 3059	26.17	0.037	13.87793	0.000	
Seed rate	HD 2967	24.42	0.2422	114.434	0.000	
	HD 3086	63.31	0.001	0.348682	0.05	
	HD 3059	64.56	0.0005	0.179927	0.02	
Yield variation (q)	Coefficient	Standard error	T	$P > \|t\|$	95% Confidence interval	
SUR model for efficiency measurements on yield variation						
HD 2967	13.39	1.217	8.54	0	7.99	12.78
HD 3086	12.39	2.93	4.23	0	6.62	18.15
HD 3059	10.34	2.77	3.73	0	4.88	15.79
SUR model for efficiency measurements on seed rate variation (kg)						
HD 2967	–27.7175	2.59	–10.70	0	–32.81	–22.62
HD 3086	–3.96	6.715	–0.59	0.555	–17.17	9.24
HD 3059	–2.90	6.84	–0.42	0.672	–16.37	10.56

Table 7. Efficacy measurements of ZT on wheat crop

Equation	Variety	RMSE	R^2	F	P	
Yield	HD 2967	12.79	0.046	17.46	0	
	HD 3086	30.66	0.007	2.84	0.09	
	HD 3059	28.89	0.026	9.662	0.00	
Seed rate	HD 2967	27.42	0.1471	61.75	0.00	
	HD 3086	60.74	0.0012	0.43	0.51	
	HD 3059	64.70	0.0002	0.06	0.80	
Yield variation (q)	Coefficient	Standard error	T	$P > \|t\|$	95% Confidence interval	
SUR model for efficiency measurements on yield variation						
HD 2967	6.0029	1.436	4.18	0	3.178	8.827
HD 3086	5.8032	3.4422	1.69	0.09	–0.967	12.57
HD 3059	10.08	3.24	3.11	0.002	3.70	16.46
SUR model for efficiency measurements on seed rate variation (kg)						
HD 2967	–24.20	3.07	–7.86	0	–30.25	–18.14
HD 3086	–4.48	6.82	–0.66	0.51	–17.89	8.92
HD 3059	–1.79	7.26	0.25	0.80	–12.48	16.08

farmers earned an additional income of at least Rs 6000/ha. Thus, applying both technologies with wheat varieties (mainly HD-2967) had the potential for additional returns throughout the country.

Constraints analysis of strategy formulation for outscaling of farm machinery

Based on expert opinion, constraints analysis showed that lack of custom hiring services (farm machinery) remained the major organizational constraint (average score = 65.8), followed by unavailability of Government support (average score = 51.55) and poor cooperation of organizations (average score = 52.85). The initial investment for purchasing farm machinery is high. So custom hiring service is a beneficial solution. Figure 5 *b* justifies the statement that large farmers would benefit more from other factors. Similar problems were reported by Loon *et al.*[7] and Arun *et al.*[8]. Besides, small and scattered land, inability to follow uniform farm techniques, unfavourable land situation and non-implementation of Government subsidy schemes, etc. resulted in low production and less income for small and marginal farmers. Non-availability of machines was the predominant technological problem (ranked first), followed by the lack of skills, expert guidance, skilled personnel for handling machines and poor technicalities for outscaling of farm machinery. The excessive cost of farm machinery has continually been a serious limiting factor in the mechanization of agriculture. Farmers in the study area pay appreciably greater money for machines than their counterparts in industrialized states like Punjab, Haryana and Uttar Pradesh. Lack of genuine spareparts of machinery at a reasonable price and a convenient distance also badly affected their operation. Thus, the lack of spare components for agricultural machinery and equipment is the primary factor affecting mechanization. Figure 5 *d* reiterates that the main problem is the low level of funds/capital (ranked first) and ineffective service of lending establishments like banks. Besides, lack of payment of subsidies and non-implementation of Government schemes also contributed to outscaling of the technology. Experts' opinions revealed that a minimum level of economic development would help adopt new technology (farm machinery).

Policy implications for outscaling of improved machinery

Following Alfares and Duffuaa's method, the aggregate weight (*W*) was calculated for each dimension (criterion), assuming 100% for rank 1 (Table 8). Economic problems (aggregate weight 1823.11) were the most important (ranked first) for upscaling and outscaling, followed by technical issues (1646.23), organizational problems (1241.92) and situational factors (1014.51).

Policy for setting up farmer's cooperatives and customized hiring services for multi-farm use is crucial. Constant provision of financial services, incentives, loans and subsidies is necessary. Improved mechanism of supply and value-chain system, dissemination of farm information, technical guidance, knowledge about farm diversification and alternative income strategy, organization of farmer producer organizations (FPO), motivation through extension system, etc. also deserve more attention. The education level of most of the farmers was poor. The majority had little or no exposure to improved machines for farm operation and were hesitant even to attempt handling motor/electricity-operated equipment. A programme to train farmers in handling and managing farm equipment is necessary to make mechanization a success. Due to a lack of technical knowledge, farmers are unable to utilize the machine properly even after hiring it. So training centres could be established in the study area by Government organizations, agricultural universities, Non-Governmental Organizations (NGOs), agriculture line departments or Krishi Vigyan Kendras (KVKs) to take up this task. The existence of hidden labour in agriculture is a major factor of low income of farmers. With ever increasing population and agriculture losing its importance as a remunerative source of income, it is difficult for the country to maintain the level of production of foodgrains. In such a scenario, agricultural mechanization is a solution to address the growing call for food grains. However, the incapacity of farmers to purchase

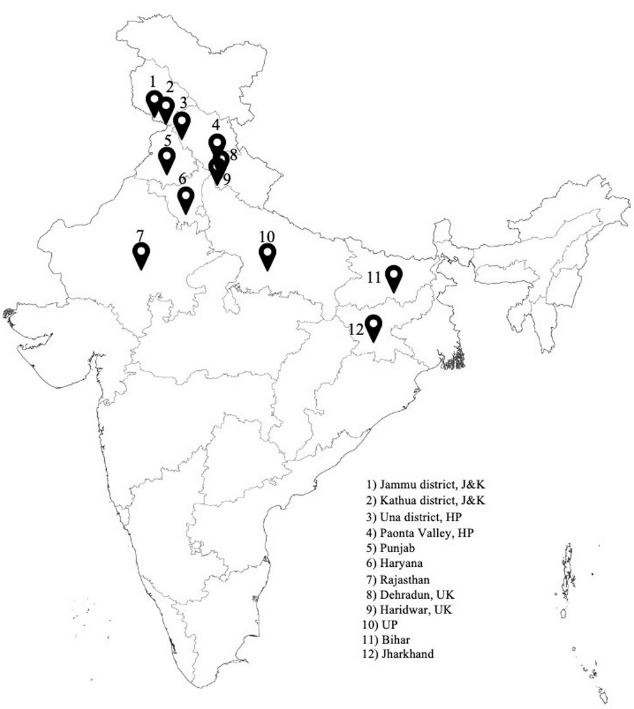

Figure 3. Agro-ecological distribution of selected improved wheat varieties.

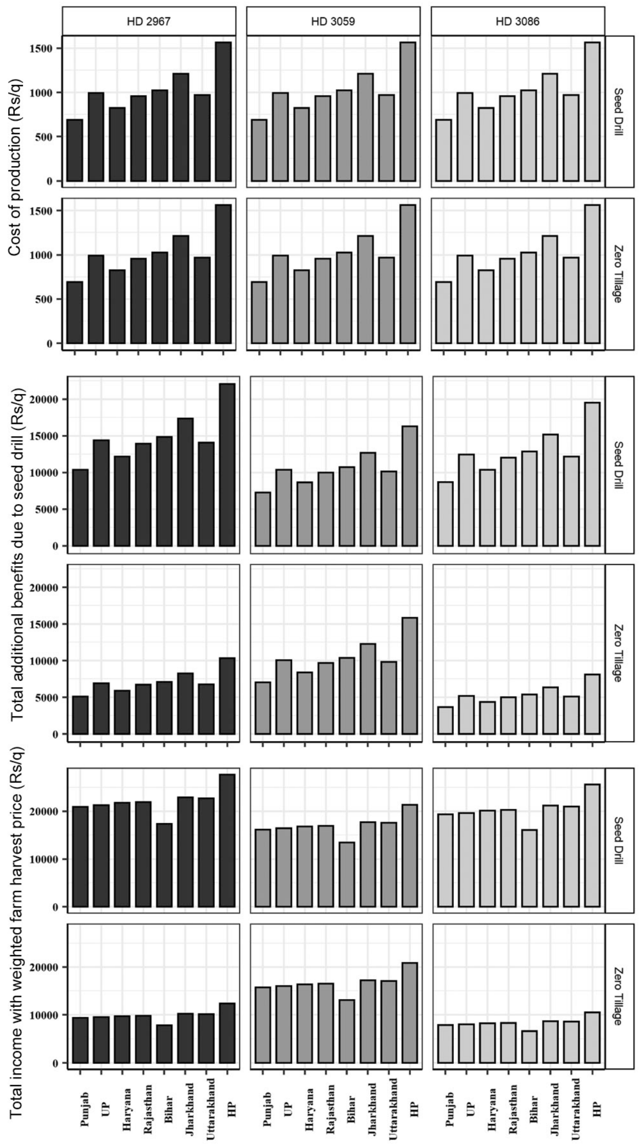

Figure 4. Wheat varieties and machinery-wise (seed-cum-fertilizer drill and ZT) farm efficiency measures in different states of India.

Table 8. Strategy for outscaling of farm machinery using Alfares and Duffuaa method (expert opinion)

	Respondents' rank				
Area	First	Second	Third	Fourth	$W_{r,n}$
Organizational problems	0	0	13	7	100
Situational factors	2	0	7	11	74.73
Economic problems	16	2	0	2	62.09
Technical factors	2	18	0	0	49.46
Frequency	20	20	20	20	
$1/f$	0.05	0.05	0.05	0.05	0.05
$W_{r,f}$ (aggregate weight)	1241.92	1014.50*	1823.11**	1646.23	
Rank	3	4	1	2	

*Least serious; **Most serious.

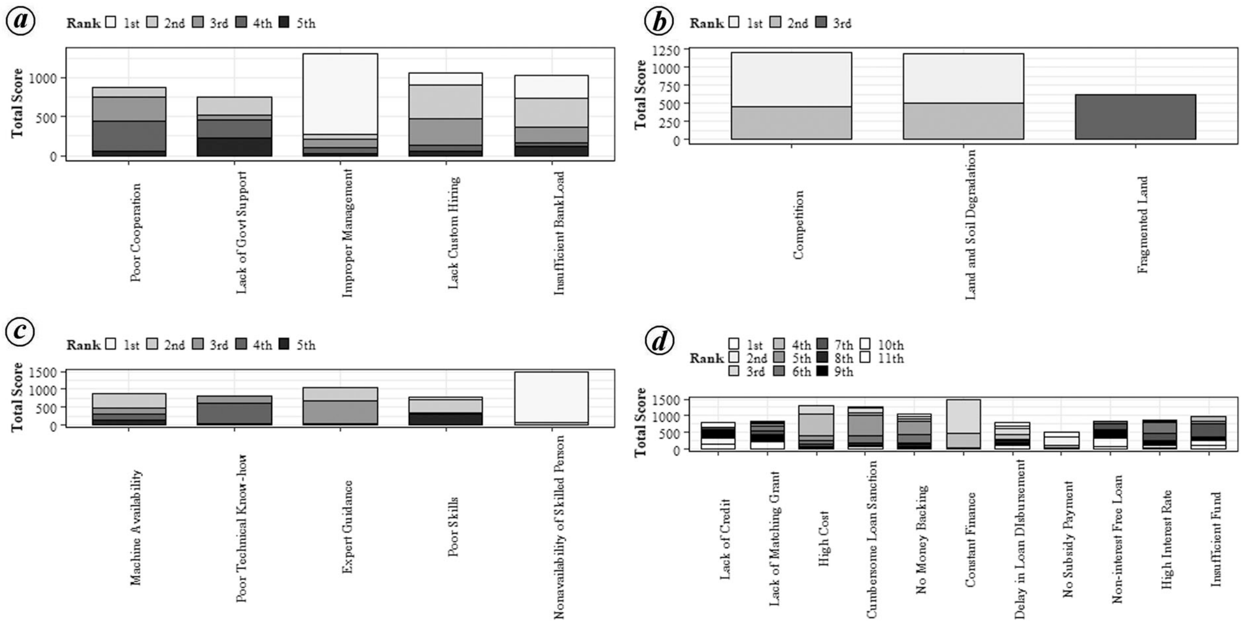

Figure 5. Constraints analysis for outscaling of machineries. ***a***, Organizational problem. ***b***, Situational problem. ***c***, Technological problem. ***d***, Economical problem.

farm implements and the reluctance of commercial banks to finance farm machinery are major obstacles to mechanization, leading to an increase in labour charges. The production of economically feasible technology for small farmers needs through government support needs to be enhanced at village level. Steps must be taken to provide meaningful and accurate information to key stakeholders to promote and disseminate this activity for customized hiring. Training may also be included to enhance consciousness among the various stakeholders. Different organizations like KVKs, NGOs, Self Help Groups (SHGs), etc. could play an important role in promoting machinery in the agricultural sector.

Conclusion

The present study found that availability of information, mass media exposure, risk orientation, innovativeness and farm assets were the significant factors affecting the adoption of farm technology. Seed-cum-fertilizer drill, operational land holding, frequency of mass media use and innovativeness were significant factors for the adoption of ZT. Seed-cum-fertilizer drill and ZT demonstrated a positive impact on agronomic and economic aspects. The wheat variety HD-2967 showed the best performance for adopting farm machinery that would lead to additional farm income. The state-wise scenario also showed the same trend. Alfares and Duffuaa's method suggested that economic problems (aggregate weight 1823.11) were the most important for upscaling and outscaling. Most farmers are resource-poor; some support systems like custom hiring centres with public–private partnership, private entrepreneurs, cooperatives, farmer's organizations and charitable trusts have been suggested. Designing feasible models of farm machinery, provision of credit and marketing, training and dissemination of information, farmers' motivational programmes, etc.

must be strategized. Increasing demand for farm machinery would help explore the opportunity for business entrepreneurship. Besides, the spill-over effect of mechanization also opens up the scope for the development of animal husbandry, dairying and fisheries sector. Hence it can be concluded that the adoption of seed-cum-fertilizer drill and ZT has a positive socio-agro-economic impact on the livelihood of small holder farmers and the sustainability of this impact can be ensured through different support systems.

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