Can Farm Mechanization Enhance Small Farmers' Income? A Lesson learnt of Lower Shivalik hills of Indian Himalayan Region

PINAKI ROY (roypinaki51@gmail.com)
Indian Council of Agricultural Research-INDIAN AGRICULTURAL RESEARCH INSTITUTE https://orcid.org/0000-0003-0374-9191

BS Hansra
Amity University

R Roy Burman
ICAR-Indian Agricultural research Institute

Sangeeta Bhattacharyya
ICAR-Central Citrus Research Institute Nagpur

Roaf A Parray
ICAR-Indian Agricultural research Institute

T N Roy
Uttar Banga Krishi Viswavidyalaya

Anirban Mukherjee
ICAR-Research Complex for Eastern Region Patna

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Abstract

Indian farming is fraught with small land holdings, and farm mechanization's economic viability has remained a debatable issue at the core of Indian agriculture's technology growth. The authors attempted to determine the socio-agro-economic impact of seed cum fertiliser drill and zero tillage through Difference In Difference(DID) method with ex-ante (before application) and ex-post (after application) approach. Results depicted labour costs were reduced by almost 80% and seed savings were reduced by 20%. The seed cum fertiliser drill and zero tillage adopters saved a sum of Rs. 3764.10 and Rs. 4047.54 from 1 ha of land, respectively. An effort was also made to quantify the additional economic benefit by using the Apparently Unrelated Regression (SUR) model to apply selected forms of machinery to different varieties. Seed cum fertiliser drill and zero tillage results have been found to increase yield by 13.39 quintals and 6.0 quintals per ha respectively and decrease the seed rate by 27.71 kg/ha and 24.20 kg /ha, respectively, for the HD 2967 wheat variety. The growth of the agricultural mechanisation sector is hindered by machine cost, the widespread existence of resource poor farmers, and inaccessibility of agricultural technology. In addition, few suggestions on critical aspects were made on the basis of the application of technology in different states to implement suitable policies for the additional financial advantage of farmers.

Introduction:

With a population of 1.2 billion, India has about 118 million farmers (main and marginal cultivators) and 144 million agricultural laborers. That is, 54.6% of the total Indian workforce bears the responsibility of ensuring the nation's food and nutritional security (Bhattacharyya et al., 2020). India has achieved self-sufficiency in food grains, which can be attributed as a bane of the Green Revolution of l960s, a cafeteria of technological improvements amongst which mechanization of agriculture played a big role. Farm mechanization is crucial for the modernization and commercialization of agriculture as it improves productivity, timeliness of operations, aids in value addition, brings down the cost of cultivation, and enables climate change adaptation. Prasad et al. (2014) had estimated farm mechanization reduces costs of seed and fertilizer by 15%; animal labour by 60%; and human labour by 20%. In wheat crop, automation resulted in yield gains of 10% and reductions in costs of up to 25% for seeds, 30% for irrigation water, and ample time saving for farm managers to do proper crop planning. The feasibility of mechanization in small farms is often questioned due to the scale of most modern implements. The types of machinery are large and not appropriate for the conditions of small and marginal farms of India, other countries of Asia, Sub-Saharan Africa, and other developing countries dominated by small landholdings. There is a huge hue and cry for scale specific/appropriate technologies. But the myth has been busted by Daum and Birner (2020), explaining that mechanization can be profitable for smallholder farmers. Seed cum fertilizer drill and zero tillage implements are two very handy machineries used efficiently in many Indian farms of small and medium-size, and the following study deals with the economic efficiency of these two implements. These are helped to improve fertilizer use efficiency, save time, water, labour, cost and escape terminal heat stress in wheat cultivation (Mittal, 2017). There is immense scope of farm mechanization and is the need of the hour. With the intensification of agriculture, there is a need for farm power availability from the present level (0.60 kW/ha) to about 2.0 kW/ha by 2020. Hence in this study, the authors have attempted to study the impact of seed cum fertilizer drill and zero tillage machine on the production, the productivity of improved varieties of wheat at lower Shivalik hills of Himalayan region. The authors have also attempted to project Uttarakhand's scenario in other states of India where these varieties of wheat are grown. This presents the scenario of out-scaling of seed drill and zero-till in wheat across India and its effect on farmers' income as farm gate prices, and cost of cultivation of that crop vary from state to state. So the article has tried to explore the necessity of up-scaling (vertical) and out-scaling (horizontal) of farm machinery, and the results were expected to generate policy implications for how the up-scaling and out-scaling can be done. Thus, there is an urgent need to enhance the level of farm mechanization in our country by redressing the states with a lower share of mechanization. How the machines perform and enhance the yield of smallholder farmers of rugged terrain and how the same can up-scaled and out-scaled to benefit several other smallholders of different states have served as the motivation behind this study.

Materials And Methods:

Locale of Study

Lower Shivalik hills, instead of adequate natural resources for successful crop growth like fertile soil, 87 percent irrigation water, the productivity was found not to reach a competitive level for the lower Shivalik region of Uttarakhand for various crops as compared to other parts of the lower Shivalik Hills (i.e., Jammu region of J&K and Malwa region of Punjab) (Yadav et al., 2015). The non-availability of improved planting materials (seed), poor access to modern technologies, and poor productivity lead to an abysmally low marketable surplus in the plains of Lower Shivalik hills Uttarakhand (Roy et al., 2018). Moreover, farm Mechanization stands at about 40-45% in UP and Punjab states, whereas little mechanization in states like Uttarakhand. So the study has been purposively conducted in the lower Shivalik hills of Uttarakhand. India's hilly state is Uttarakhand, situated in North Western Himalayas.

Sample size determination

The Cochran formula (1977) has been used to calculate an ideal sample size given a desired level of precision, desired confidence level and the estimated proportion of the attributes present in the population. The Cochran formula is:

$$\mathrm{n0} = \frac{Z2pq}{e2}$$

where,

- e is the desired level of precision (margin of error)
- p is the (estimated) proportion of the population which has attributes in question
- q is 1-p
- The z-value is found to be 1.96

In the present study, authors do not have much information on the subject to begin with, so going to assume that half of the farmers have adopted that particular farm machinery that give maximum variability. So p = 0.5. Now considering 95% confidence and at least ±5 percent precision, authors assume more than 95% confidence level gives Z value of 1.96, per the normal table, so get

$((1.96)^2 (0.5) (0.5))/ (0.04)^2 = 359.23$

Hence the sample size was approximately 360. Apart from these 20 government officials (Krishi Vigyan Kendra Scientists and extension functionaries of the state department of agriculture) have been interviewed to suggest suitable policy for upscaling and out scaling of adoption of improved technologies by farmers in the particular region. Thus, a total sample of 380 respondents were selected for this study.

Statistical tools and software:

Binary logistic regression was used to find out the factor affecting farmers' decision to adoption of particular technologies (Seed cum fertilizer drill, Zero tillage). It is assumed that the binary response, Y, takes on the values of 0 and 1 with 0 representing non adoption of particular machinery and 1 representing adoption of particular machinery. The equation is as follows

$$Y = \ln\left(\frac{Pi}{1-Pi}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + €$$

Where *Pi* is a probability of farmers decision, *Pi* = 0 indicates adoption and *Pi* = 1 indicates non adoption

Y = probability of farmers decision

β_0 = intercept

$\beta_1 - \beta_8$ = regression coefficients of the dependent variables

X_1 -X_{19} = Independent variables

In addition to these, **Kendal tau** has been used for find out the degree of association with different independent variables. Kendall's tau is computed as $\tau = Nc - Nd / Nc + Nd$

where N_c and N_d denoting the number of concordant pairs and the number of discordant pairs, respectively, in the sample. Ties add 0.5 to both the concordant and discordant counts.

Seeming Unrelated Regression (SUR) Model was employed to estimate the economic efficacy of a particular farm machinery with respect to varieties. The SUR method estimates the parameter of all equations simultaneously, so that the parameters of each single equation also take the information provided by the other equations into account. This results in greater efficiency in estimation by combining the information on different equations.

$\ln \Pi i^* = \ln Ai^* + \mu i1^* \ln p + \mu i2^* \ln r + \mu i3^* \ln w + bi1^* \ln K + bi2^* \ln T + bi3^* \ln D$

Where :Πi^* = production function , P,r, w, k…… = quantity of inputs

Alfares and Duffuaa's (2009) methodology was used to find out the factors for upscaling of technologies, which is based on a linear rank-weight function whose slope (Sn) depends on the number of criteria (n). In the present study, an effort was given to determine aggregate criteria weights of each dimension or statement; the 20 judges ranked the statements within each dimension as well as each dimension. Thus, after obtaining aggregate weights, the important aspects of strategy development for up-scaling and out-scaling can be identified.

$$\mathrm{Sn} = 3.19514 + \frac{37.75756}{n}, \ \mathrm{Wrn} = 100 - \mathrm{Sn}(\mathrm{r} - 1)$$

Where, n= number of criteria, r = rank assign to statement or criteria, Wrn= weight assign to criteria based on individual rank, W= aggregate weight of respondent.

Garett ranking technique has been employed to find out the most significant factor which influences the respondent and the outcomes of such ranking have been converted into score value with the help of the following formula: Percent position = 100 (R_{ij} – 0.5) N_j

Where R_{ij} = Rank given for the ith variable by j^{th}respondents ,N_j = Number of variable ranked by jth respondent. Moreover, to calculate profitability of technologies following calculation has been taken into consideration.

The data have been analysed SPSS V16.0, STRATA_12, R 4.0.3

Results And Discussion

Extent of adoption of farm machineries

Only 45 percent of farmers had adopted seed cum fertilizer drill, and the rest, 55 percent, did not adopt it. Among the adopter farmers, more than 65 percent of farmers used seed cum fertilizer drill in the range of 6.60 to10.69 acres of land, which fell in the group of medium and about 16 percent farmers in the category of low as well as and high category. In zero tillage, only 32.78 percent of farmers had adopted, and 67.22 percent still belonged to the non-adopter category. This dossier was matched with the outcome of Mottaleb *et al*, 2016.

Discussion explored the prerequisite condition for adopting farm machinery was large operational land. However, most of the farmers were small or marginal farmers. The land was also scattered over many areas were the reason of lower adoption. Financial limitations were another impeding factor that refrained them from adoption. Farmers were solely resourcing poor and were not able to purchase farm machineries. They were not able to recognise the use as well as the working mechanism of farm machinery. Another significant reason for non-adoption was the unavailability of machinery on a custom hiring basis as well as availability to auxiliary parts and maintenance thereof. Focus group discussion implied peoples' mindset and the potentiality to make farmers aware of the farm machineries and benefits were the main reasons for non-adoption. However, once the crop germinated, other farmers wanted to know how they accomplished the results and were persuaded that it would work, although many waited until the harvesting was done for the final decision (seeing and doing). Since farmers rely upon farming for a livelihood, they will change production practices after being convinced.

Table 1: Extent of adoption of farm machineries (N=360)

Farm Machinery					
Seed cum fertilizer Drill (N=360)					
Adopter				Non-Adopter	
F	%			F	%
161	44.72			199	55.27%
Frequency distribution of adopter categorisation based on 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	%			F	%
118	32.78			242	67.22
Frequency distribution of adopter categorisation 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		

Determinants of adoption of Seed cum fertilizer drill and Zero tillage

The observed adoption choice of farm machineries was speculated to be the consequence of a tangled set of inter-technology favoured evaluations created by farmers. It was obligatory to scrutinize the elements persuading the adoption of farm machineries by evaluating a binary logic model with independent variables. This model represented the cumulative outcome of the explanatory variables impeding or encouraging the adoption of farm machinery. For Seed cum fertilizer drill, the Pseudo R^2 value showed that the model is a 91 percent best fit (Table 2). Log-likelihood function -22.30 and LR Chi^2 value 450.44 (significance 1%) suggested that the equation was fit and explanatory variables used in the model were cumulatively capable to elucidate determinants and magnitude of adoption. This model also constituted odds ratios and 95% confidence intervals for them for testing the hypothesized relationships. Similarly, for Zero tillage**,** Pseudo R^2 value showed that the model is a 40 percent best fit than any other model. The log probability function -140.99 and the LR Chi2 value 171.48 (significance 1 percent) indicated that the framework was optimized and that the explanatory variables shown in the equation might altogether elaborate the determinants and the scale of adoption.

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 of adoption. The odds ratio indicated that with a one-unit increase in available information, the adoption level could increase by 5.15 percent. Similarly, with a one-unit increase in mass media exposure, the adoption level had risen by 2.02 percent. With one unit increase of risk

orientation, innovativeness, and farm asset, the adoption level increased by 0.76, 1.13, and 13.73 percent, respectively. A similar study was carried out by Ainembabazi *et al*, 2017, which reported that accessibility of information enhanced awareness level, which eventually increased the adoption of technologies.

Table 2: Binary Logistic Regression analysis for determinants of adoption

Binary Logistic Regression analysis for determinants of adoption						
Independent variable	**Seed Cum Fertilizer Drill**			**Zero tillage**		
	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
Freq 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
_cons	3.02	-1.44	0.15	2.14	-5.46	0

*significance 1%, **significance 5%, *** significance 10%

More mass media exposure enhanced ability to procure, analyse and elucidate information of using seed cum fertilizer drill. This discovery is following the studies of Feder *et al*. (1985). Farmers had more data sources that would increase the capabilities of decision-making to embrace seed cum fertilizer drill. Farmers with more risk-bearing capacity, sometimes, lead to higher adoption as compared to other fellow farmers. They could resist with success as well as failure, simultaneously leading to more adoption. Focus group discussion with the non-adopted farmers disclosed that before adoption, they thought more about the outcome. They thought of using seed cum fertilizer drill could not have any significant increase in yield. Similarly, the numbers of farm assets had significant involvement in this regard. It referred that the farmers who had higher financial resources purchase more farm assets for use in their field. So, it can be expressed that establishing a custom hiring center is mandatory, which would increase more adoption of machinery. As anticipated, operational landholding (OLH) has an upbeat and noteworthy collision on zero tillage technology adoption. With the increase of every added unit of an acre of land, the chance of adoption was increased by 1.27 percent. On average, the result of zero tillage machine manifested that farming with each additional acre of land had enhanced the number of an acre of land under by wheat cultivation. Level of utilisation of agricultural operation quantified the number of trips per month by the extension representative to a farmer who had a favourable and meaningful impact on adoption with the likelihood of adoption by 1.13%.

To measure the ordinary linkage among two quantities, Kendall tau coefficient was employed. In this Fig 2, crucial independent variable had been picked up to measure the determinants of the level of adoption for seed cum fertilizer drill. Fig 2, showed that accessibility of information (0.45), mass media exposure (0.26), innovativeness (0.25) and farm asset (0.78) had significant positive with adoption level for seed cum fertilizer drill. Farmers with more access to information and mass media exposure had more awareness regarding the uses of resources efficiently which, in turn, lead to increase of income. Similar finding was also reported by Beyene and Menale, 2015. In case of Zero tillage adoption, Fig 2 indicated that frequency of use (0.26) and innovativeness (0.43) had significant positive relation with adoption level. It could also be concluded that with increase of mass media, awareness might be increased as well as farmers could understand the benefit of zero tillage. Hence, adoption levels automatically increase with innovativeness.

Socio-Agro-Economic impact of farm machineries:

Social impact mentioned the adoption of farm machineries that lead to any change in an individual, family, and community well-being like time-saving, employment generation, depletion in labour requirement, etc. Agronomic impact referred to change in parameters like coverage (field

capacity), seed rate, germination percentage, crop establishment, plant population per ha, etc. Economic aspects dealt with BCR (benefit-cost ratio), Net Return, and RR (rate of return) from adopted technologies.

An attempt had been made to note down the influence of seed cum fertilizer drill adoption on socio- agronomic issues. DID method was applied to evaluate the technical as well as social features with ex-ante (before application) and ex-post (after application) analytical approach. Table 3 showed the attributes of the findings therein. Results depicted that labour cost was lessened by nearly 80 per cent from 9.82 MD to 2.80MD which was followed by saving of seed by more 20 per cent from 151.04 kg/ha to 108.65 kg/ha. Similar finding was reported by Dongarwar *et al*, 2015. Apart from it all others aspects represented positive impacts in contrast to non-adoption of seed drill. Hence, farmer could have got financial advantages for adoption of seed cum fertilizer drill in farming operations. Besides, performance in various aspects showed same results as found without adoption for all non-adopters of seed drill in their farming. Similar finding was reported by Kumar and Umesh, 2018; Rawat *et al*, 2007, Singh et al, 2017

Table 3: Impact of Seed Cum Fertilizer Drill adoption on Socio-agronomic aspects (DID method) (N=360)

Particulars	Seed Cum Fertilizer Drill				Zero Tillage			
	Adopter (n=161)		Adopter (n=161)	Non Adopter (n=199)	Adopter (n=114)		Adopter (n=114)	Non Adopter (n=246)
	After	Before			After	Before		
Field capacity (Hour/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

Positive impact of ZT technology application was found to be very convincing on all aspects of agronomic as well as economics issues (field capacity, seed rate, labour, germination, establishment, plant population and nutrients) taken into account in the study. Differences in performances were very prominent when compared with or without (before) adoption of ZT by the same farmers. Among them, labour requirement was reduced by 30 per cent from 8.3MD to 2.69 MD. Related conclusion was reported by Yogi *et al*, 2015, Iqbal *et al*, 2002, Performances of the non-adopters were also studied which also established the same response as obtained in case of before adoption in all respects. Hence, adoption of ZT helped farmers to increase productivity as well as net return in farming. Similar study carried out by Verma and Tamrakar, 2017 reported similar finding.

Economic impact of adoption of seed cum fertilizer drill

Estimated fixed cost of seed cum fertilizer drill owner was Rs. 362.75 per year and variable cost was Rs. 11619.32. Total costs incurred for seed cum fertilizer drill owner per year was Rs.11982.07 and total return from the machine was Rs. 51479.26. The net benefit over investment was Rs. 39504.09 per year. Estimated return from use of it from own farm was Rs.1479.26. Farmers inferred on an average, 50 days in a year on custom hiring basis with Rs.1000 per day. As a result, return from custom hiring was Rs.50000 in a year. Value of benefit -cost ratio and rate of return for using seed cum fertilizer drill machine was 1:3.29 and 329% respectively. Further, expenditure had been worked out for conventional method (broadcasting) before adoption of seed cum fertilizer drill. It was observed that total cost incurred in sowing of wheat through broadcasting method was Rs. 15746.17. Compare the cost of sowing through seed cum fertilizer drill and broadcasting, established seed cum fertilizer drill saved an extra (Rs.15746.17-11982.07) Rs. 3764.10 from 1 ha of land.

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

Economic Analysis 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 own Seed cum fertilizer Drill		Broadcasting		Seed cum fertilizer Drill		Broadcasting	
1. Fixed costs	Rs (per/year)	1. Variable costs	Rs. (per ha)	1. Fixed costs	Rs (per/year)	1. Variable costs	Rs. (per ha)
Interest costs	361.25	Seed cost (Rs/ha)	6037.78	Interest costs	361.25	Seed cost (Rs/ha)	6030.75
Insurance and taxes	0.00	Manpower cost (Rs/ha)	3928.40	Insurance and taxes	0.00	Manpower cost (Rs/ha)	3973.87
Depreciation costs	1.50	Expenditure on NPK (Rs/ha))	3800	Depreciation costs	1.50	Expenditure on NPK (Rs/ha))	3806.23
Total fixed costs	362.75	Land preparation cost	1980.00	Total fixed costs	362.75	Land preparation cost	1980.00
2. Variable costs		Total	15746.17	2. Variable costs		Total	15790.85
Fuel cost	285.00			Fuel cost	285.00		
Land preparation cost	1980.00			Land preparation cost	1980.00		
Seed cost (Rs/ha)	4343.89			Seed cost (Rs/ha)	4343.89		
Lubricant cost	4.25			Lubricant cost	4.25		
Manpower cost (Rs/ha)	1121.74			Manpower cost (Rs/ha)	1121.74		
Expenditure on NPK (Rs/ha))	2884.44			Expenditure on NPK (Rs/ha))	2884.44		
Maintenance cost	1000.00			Maintenance cost	1000.00		
Total variable costs	11619.32			Total variable costs	11619.32		
3.Total costs	11982.07			3.Total costs	11982.07		
4.Return from own farm	1479.26						
5.Income from custom hiring	50000						
6.Total income	51479.26						
7.Net income	39504.09						
BCR for Seed drill: 1:3.29		Paired t test	126.36***			Independent t test	62.55***

**Price of Seed cum fertilizer drill: Rs. 50000/ unit (Unit costs for investment activities in agriculture and allied sectors Uttarakhand 2019- 20)
*** Significance 1%

Table 4 presented comparative economic analysis of adopter and non-adopter. It was witnessed in case of non-adopter, cost incurred for sowing of 1 ha was Rs. 15790.85 whereas Rs.11982.07 for adopted farmers. If compared with expenditure on sowing between adopter and non-adopter, it was found that adopter had saved Rs. (15790.85-11982.07) *i.e.*, 3808.78 by adoption of seed cum fertilizer drill. An identical study was carried out by Satish and Umesh, 2018 reported that mechanized sowing of rabi crops were more profit making in financial terms rather than the conventional one. Both paired't'-test (with in adopter) and independent t test (between adopter and non-adopter) value specified that there was positive significant difference in sowing cost.

Economic impact of adoption of Zero tillage

Estimated fixed cost of Zero tillage owner was Rs. 378.6 per year and variable cost was Rs. 9805.43. Total costs incurred for zero tillage owner per year was Rs.10184.06. and return from the zero tillage machine was Rs. 51568.64. The net benefit over investment was Rs. 41384.59 per year (Table 5). Fixed cost was the 0.91 percent of the overall gain whereas variable cost was 23.69 percent of the total compensation. Value of benefit-cost ratio and rate of return for using zero tillage machines was 1:4.06 and 406% respectively. In the contrary, expenditure had been worked out for conventional method (broadcasting) before adoption of zero tillage. It was found that total cost incurred sowing of wheat through broadcasting method was Rs. 14063.92. Comparing the cost of sowing through zero tillage and broadcasting, it was found that zero tillage saved an extra (Rs.14063.92-Rs.10184.06) Rs. 3879.86 from 1 ha of land.

Table5: Comparative economic analysis of ZT and broadcasting

Economic Analysis zero tillage and broadcasting (n=114)				Economic analysis of Zero till adopter and Non-adopter (n=360)			
Adopter category				Adopter		Non-Adopter	
Farmer own zero till		Broadcasting		Zero till		Broadcasting	
1.Fixed costs	Rs (per/year)	1. Variable costs	Rs. (per ha)	1.Fixed costs	Rs (per/year)	1. 1. Variable costs	Rs. (per ha)
Interest costs	375.7	Seed cost (Rs/ha)	5374.576	Interest costs	375.7	Seed cost (Rs/ha)	5545.528
Insurance and taxes	0	Manpower cost (Rs/ha)	3320.339	Insurance and taxes	0	Manpower cost (Rs/ha)	3317.073
Depreciation costs	2.93	Expenditure on NPK (Rs/ha))	3389	Depreciation costs	2.93	Expenditure on NPK (Rs/ha))	3389
Total fixed costs	378.63	fuel cost	1980	Total fixed costs		Fuel cost	1980
2. Variable costs		Total	14063.92	2. Variable costs		Total	14231.6
Fuel cost	285			Fuel cost	285		
Land preparation cost	0.00			Land preparation cost	0.00		
Seed cost (Rs/ha)	4024.57			Seed cost (Rs/ha)	4024.576		
Lubricant cost	4.28			Lubricant cost	4.28		
Manpower cost (Rs/ha)	1074.58			Manpower cost (Rs/ha)	1074.58		
Expenditure on NPK (Rs/ha))	3417			Expenditure on NPK (Rs/ha))	3417		
Maintenance cost	1000			Maintenance cost	1000		
Total variable costs	9805.43 (23.69)			Total variable costs			
3.Total costs	10184.06			3.Total costs	10184.06	Independent t test: 114.50***	
4.Return from own farm	1568.64						
5.Income from custom hiring	50000						
6.Total income	51568.64						
7.Net income	41384.59						
BCR for ZT: 4.06		Paired t test= 30.098***					

Value in parenthesis indicate percent of cost with respect to net income, *** Significance 1 %

Table 5 presented comparative economic analysis of adopter and non-adopter. It was found that in case of non-adopter, cost incurred for sowing of 1 ha was Rs.14231.60 and in case of adopter, it was Rs. 10184.06. In case of adopter, net return over cost was Rs. 41384.59. The B:C value of adopter of zero tillage machine was 1:4.06. If compared to the expenditure on sowing between adopter and non-adopter, it was found that adopter had saved Rs. (14231.60- 10184.06) 4047.54 by adoption of zero tillage machine. The comparable outcome was stated by Yogi *et al*, 2015.Results of paired t test (with in adopter) as well as independent 't'-test (between adopter and No adopter) implied positive significance difference between zero till sowing adopter and non-adopter (Broadcasting). Similar finding was reported by Verma *et al*,2018, Krishna and Prakashan, 2014.

Farm level efficiency of improved machineries for upscaling:

This part is focused on devising an approach for out scaling of selected technologies for Lower Shivalik range of Uttarakhand as well as other regions on lower Shivalik hills. It alludes to the most suitable variety of wheat crop, for that particular region in economic parameters and economic efficacy of each machinery, related to each selected improved varieties in lower Shivalik hills. It aids farmers to step up agricultural production and income which results in economic growth, redistribution of resources at individual, local and regional level.

To estimate economic efficiency (in terms of yield and seed rate quantity) of seed cum fertilizer drill on selected wheat varieties, Seeming Unrelated Regression (SUR) model has been adopted. In the Table 6, RMSE score 11.48 shows model presents 11.48% absolute fit of predicted results of yield estimation of HD-2967 by using seed drill than OLS (Ordinal least Square) model. It presents 27.63% and 26.17% absolute fit predicted results for yield estimation for HD-3086 and HD-3059 than OLS model. In the similar way, model present 24.42%, 63.31% and 64.56% more efficient absolute predicted results for seed rate estimation in HD 2967, HD 3086 and HD 3059, respectively. Lesser RMSE values instructed for better fit. Here RMSE value 11.48 indicated in Table 6 that Yield estimation of HD 2967 is the best fit model**.** The data in Table 6 explains the efficacy of seed drill on yield and seed rate of different wheat varieties. It was observed that the use of seed drill enhances 13.39 q more yield per ha for the variety HD 2967. The varieties HD 3086 and HD 3059 have 12.39q and 10.34q more yield per ha respectively when sown through seed drill. Similarly, it was found that use of seed drill lessened seed rate by 27.71 kg/ha for HD-2967 which was followed by 3.96 kg/ha and 2.90 kg/ha for HD 3086 and HD 3059, respectively.

Table 6: Efficacy Measurements of Seed Drill on Wheat Crop

Equation	Variety	RMSE	R-sq	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	
SUR Model for efficiency measurements on yield variation						
Yield Variation(q)	Coef.	Std. Err.	T	P>|t|	[95% Conf.	Interval]
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 explain the efficacy of zero tillage on yield and seed rate for different wheat varieties. It was observed that use of zero tillage enhance yield by 6.00q more per ha for the variety HD2967. The HD 3086 and HD 3059 have 5.08q and 10.08q more yield per hectare, respectively when sown by zero tillage. As such, it was found that of use of zero tillage adoption helps to, seed rate reduction 24.20 kg per ha in case 2967 which was followed by 4.49 kg and 1.79 kg per ha for HD 3086 and HD 3059. Thus, it saved the cost of seed which, in turn, increased farmers' net income.

Table 7: **Efficacy Measurements of Zero Tillage on Wheat Crop**

Equation	Variety	RMSE	R-sq	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	
SUR Model for efficiency measurements on yield variation						
Yield Variation(q)	Coef.	Std. Err.	T	P>|t|	[95% Conf.	Interval]
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

Scenario Building and Synchronous Bootstrapping Towards Farm Mechanization:

In view of the efficacy of above discussed machineries on wheat varieties, an attempt has been made to study the improved varieties of wheat grown all over India in the context of future prospects of scaling up of these varieties in those particular regions where the usage of machinery in cultivation of these crops can lead to enhanced production and productivity.

Based on the above results, an effort has been made to present the state-wise scenario in respect of economic benefits where these varieties are grown and the selected mechanizations have been done. Fig 4 presents the scenarios of farm income for application of seed drill and zero till with reference to wheat varieties. Estimates based on the state-wise secondary data on cost of cultivation (Rs/q), price of seed (Rs/kg), farm harvest price (Rs/q) showed that the cost of cultivation (Rs/q) was the lowest in Punjab. It implied that farmers earned an additional benefit of at least more than Rs. 13000/- per ha and varied according to the cost of production. Similarly, for HD 3086 and for HD 3059, it was at least Rs. 10,000/ per ha each.If the farmers sold their product at MSP, they could earn additional income of Rs 24107.85/-, Rs22797.6/ and Rs.19026.74/- per ha from grain yield with respect to variety HD-2967, HD-3086 and HD-3059. But farmers reported that they were forced to sell their product at farm harvest price which was below the rate of MSP.

Considering this, estimation was made which afforded an additional income ranging Rs 20000-25000/- per ha for variety HD-2967, Rs. 16094.61-25622.52/- per ha for variety HD-3086 and Rs.13432.47-21384.4/ per ha for HD-3059 respectively. In case of Zero till, it implied farmers earned an additional benefit of at least Rs. 6000/- per ha which is varied according to the variety and cost of production. The farmers selling their product at MSP, could earn additional income of Rs 11040/-, Rs9347.20/ and Rs.18547.20/per ha from grain yield with respect to variety HD-2967, HD-3086 and HD-3059. In case for Farm Harvest Price, estimation was made which afforded an additional income ranging Rs 10000/- -Rs. 21000/ per ha which varies variety wise.

Constraints analysis for strategy formulation for out scaling of farm machineries

Expert opinion has been taken to identify the constraints related to out scaling of farm machineries.

According to experts view point lack of custom hiring services (farm machinery) was the major Organisational constraint (average score of 65.8) followed by unavailability of proper government support (avg score 51.55), poor cooperation at grass root level organizations (avg score 52.85).Related discovery was conveyed by Loon *et al*, 2020 and Gowda, 2012, Kelsey 2011, Balachandran, 2004. The custom hiring service could also be fruitful solution for using machinery as the initial investment was comparatively high. Another fascinating apprehension spot lighted that custom hiring farmer that possession of the tractor could be a sign of aristocracy in this sort of circumstances, indeed little ranches purchased tractor which turns into obstruction in customized hiring services. Hence it is imperative to create additional awareness regarding custom hiring of machinery which can facilitate to reduce the fixed costs of farm operations and lessen the burden of heavy capital investments.

Experts advised that farmers had to confront multidimensional problem for adoption of farm machinery and, as consequence, it had reflected to the level of up-scaling and out-scaling of farm machinery. As small and marginal farmers were predominant in the study area and they were no longer in a position to compete with the rich farmers. Thus, the Fig 5b showed competition with large and resource rich farmers was the main situational problem and accordingly got first rank which was followed by land fragmentation of holdings, soil and land degradation with avg. score of 59.5 and 31 and stationed at the 2nd and 3rd position, respectively. Similar problems had been reported by Loon *et al*, 2020, Balachandran, 2004 Arun *et al*, 2019. Rich farmers were benefitted from the different government subsidy schemes. Most farmers own sets of separate small and scattered plots. In some cases it used to be beyond the location of the village too, which made it impossible for them to use uniform farming techniques on their entire holding. Therefore, farmers were unable to use the equipment effectively. Henceforth, farm mechanization of scattered, parcels of land became too troublesome and inefficient, which, in turn, reduced agricultural production and owner's incentive for land improvement and accomplishment of high production.

Non-availability of machines was the predominant technological problems (rank first) for out-scaling of farm machinery. Moreover, lack of skills, expert guidance, skilled personnel for handling machine and poor technicalities were also correlated with the technical problems of out- scaling of machinery. This finding lies with Kelsey, 2011, Balachandran, 2004. Availability of spare components was being imported. Similar finding was reported by Gowda, 2012. It is assumed that lot of attempts have to be taken up in this sector for mechanization of agriculture in this area for which govt. initiatives are assumed to be more important.

Dearth of manufacturers in the state led to buying of farm implements from other states. It required excessive capital investment for a small farm which made it uneconomical for small farmers. The excessive cost of farm machinery had continually been a serious limiting element in mechanization of agriculture. Farmers in this study area pay appreciably greater for machines than their counterparts in industrialized states like Punjab, Haryana, and U.P. Lack of genuine spare parts of machinery parts at a reasonable price and at a convenient distance had badly affected the operating of machines. Thus, lack of spare components for agricultural machinery and equipment used to be a primary trouble which notably affected all mechanization.

Fig 5d reiterated that the main problem is low level of fund/capital (ranking first) which stands in the way of agricultural development on the part of the small and marginal farmers who dominated the farming. This finding was also reported by Baliwala et al, 2017. Acquiring of fund is possible through credit but is has lot of lacunae and, as such, delay in loan disbursement by bank was given the 2nd rank. It was followed by more cost of machine and higher interest rate of loan. This verdict was matched with the judgement of Loon *et al*, 2020 and Gowda, 2012. Besides, lack of payment of subsidy and non-implementation of govt. scheme and inefficient service of bank (rural) are also recorded towards out-scaling of the technology. This finding lies with Kelsey, 2011, Balachandran, 2004. Hence, awareness about the govt. credit facilities and accountability of implementing agencies may be taken into consideration while framing any govt. policy in this regard. More than 70 per cent farmers have been economically poor. Due to this financial condition, in spite of their willingness to own farm implements, they were unable to purchase as these did not come in their order of priority of day to day requirements. Majority of the farmers having small farm holdings couldn't bear to save capital out of their own investment funds to purchase farm implements. If farmers had to take care of each tractor drawn and animal drawn implements, it might be uneconomical. On discussion with the experts it was disclosed that the farmers of that region facing unbelievable trouble in availing credit facilities for the purchase of implements.

They reported that huge formalities and a numerous visits were essential for availing credit facility. They additionally feared as to how many times they would be needed to reimburse the deposit obtained on account of suspected foul play in societies. They enquire interest free credit for buying implements and machinery. Moreover it was found that majority of farmers were having poor educational status and were unaware of such

facilities. Some of them who were eager to take benefit of modern technology were excessively poor and could not mortgage their property to secure a bank loan. In addition, banking services had not been proper in rural areas. Indeed, even if it was accessible, farmers had not been well trained to take advantage of the banking facilities. They weren't habituated to deposit their cash in a bank or required a loan from a bank and refund it. Henceforth, it is needed to educate them, to expose them to banking and make them habitual of using bank. Thus lack of well organised workshops in the areas has made it hard to carryout mechanization programmes programs effectively.

Strategy for out-scaling of improved machineries (Expert Opinion):

Following Alfares and Duffuaa method, the aggregate weight (W) has been calculated for each dimension (criteria) assuming 100% for rank-1 which is evident from the Table 8. Economic problems (aggregate wt. 1823.11) were the most serious problems having first ranked for up-scaling and out-scaling of machinery followed by technical issues (1646.23), organisational problem (1241.92) and situational factors (1014.51) with rank of 2nd, 3rd and 4th, respectively.

Average size of operational holdings is shrinking resulting in higher proportion of marginal and small holdings hence making possession of agriculture equipment economic and unviable. Establishment of Farmer's Cooperatives and Farm Machinery Utilization Centres or customized hiring service for multi-farm use are crucial. Necessary steps for improvement of supply chain and value chain mechanism must be developed and communicated to the farmers. Financial incentives, sponsored loans, low interest rate, provision of training will motivate the farmers for using farm machinery. Besides, dissemination of information, technical guidance and alternatives farm income may be promoted collectively. But poor information dissemination refrained them from use and management of those expensive resources. Experts felt that this drawback may be resolved by introducing joint farming or farming on co-operative basis resulting in increase in farm holding size. Other organizations like KVK, NGO, SHGs, etc. may play an important role for promotion of machinery in agricultural sector.

Table 8: Strategy for out-scaling of farm machineries by Alfares and Duffuaa method (Expert Opinion):

Areas	Respondents' rank				
	1st	2nd	3rd	4th	Wr,n
Organisational 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
Wrn,f (aggregate weight)	1241.92	1014.50*	1823.11***	1646.23	
Rank	3	4	1	2	

*** Most serious * Least serious

Therefore, the extension programmes of agricultural engineering ought to be strong. This was reflected in the perception of farmers and use of farm implement and machinery. Similarly manufacturers have not been accessible. This was because of poor extension intervention towards this path. Henceforth mechanisms and incentives should be put in place to encourage the procurement of machinery by smallholders and a favourable tax, liability, and/or excise regime should be enforced. Relevant economic instruments need to be established in this setting to placed small farmers into the financial aid beneficiary circle. It is important to consider whether farmers in real need of access to loans are excluded because of their ineligibility under established criteria. They were determined to prepare for land consolidation by government agencies. Such consolidation might improve cooperative farming or mechanized farming. The education of most of the farmers was poor. The majority of farmers have very little or no exposure to improve machines for farm operation and were hesitant to even attempt handling motor/ electric operated equipment. A programme of farmers training in handling and managing farm equipment used to be felt an urgent need to make mechanization a success. Custom hiring is a successful strategy to promote mechanization and tackle numerous constraints for the overall improvement of the agricultural sector, such as labour shortage, climatic disasters, as well as timely bound activities. It was orated that farmers had been looking for hands-on training experience starting from tractor driving, hitching of implements, ploughing, harrowing, seed sowing, cultivating, spraying, dusting, harvesting, and their repair and maintenance. They also want a knowledge/training programme for restoring and renovating diesel engines and electric motors. Due to the lack of perfect technical knowledge they had been unable to utilize the machine properly even after hiring it. So it has been conveyed that training centers might be established in the study area either by government organizations, agriculture universities, NGO, Agriculture line departments, or KVK to take up this task. It may be referred to that a higher percentage of labour association in agriculture with a lower contribution to GDP creates agriculture even less satisfying is the cause of ranchers' destitution. With the estimation of reverse fashion in the populace and agricultural growth, it will undesirably effect on production. In such scenario agricultural mechanization is an answer to address the trouble of growing call for of food grains. However, farmers' incapacity to buy farm implements and commercial banks' reluctance to finance farm machinery is one of the major obstacles to the rise in the pace of mechanization which leads to an upward push in entering costs attributable to labour charges. The production of economical technology alongside state support for tiny farmers needs to be checked out and encouraged at the village level, often near the place where small and marginal farmers live. Custom Hiring Centres (CHCs) must be formed through Public-Private Partnership (PPP), non-profit organizations, co-operative foundation, farmer groups, and charitable trusts. A few governments like Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Punjab, etc have been endorsing farm mechanization through CHCs and such endeavours should be ventured up. Governments must catalyze to inspire them and enable farmers to recognize new economic models, such as custom hiring. In this particular circumstance, cross-sectoral collaborations with the non-

government segment, financial institutions, and farmers' associations must be pursued to focus the numerous monetary blessings of customized hiring and the possible contribution in the direction of modernizing agricultural operations and improving rural livelihoods. Steps need to be taken to provide meaningful and accurate information to key stakeholders to promote and disseminate this activity for customized hiring. Besides, it is important to encourage proper communication along with the value chain including the dissemination of information on the overall performance of agricultural machinery, appropriate training modules developed, and regular training sessions organized to train people involved in machine operations and those involved in repair and maintenance services. Training may also add an instrument to make bigger consciousness among the various stakeholders.

Conclusion:

The study found 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 of adoption of seed drill whereas, operational land holding (0.01**), frequency of mass media use (0.01**) and innovativeness (0.00**) were significant factors for zero tillage adoption. Evaluation of seed drill and ZT technology exhibited positive impact on all aspects of agronomic (field capacity, seed rate, labour, germination, establishment, plant population and nutrients) as well as economics issues (BCR and Net Return).The efficacy of farm machinery showed that seed drill enhances yield at maximum level for the variety of HD2967 and saved seed rate by 27.71 kg/ha. Similarly zero tillage enhanced the maximum yield of HD 3059 by 10.08q/ha. Use of zero tillage reduced seed rate by 24.20 kg per ha in case of HD-2967 which was followed by 4.49 kg/ha and 1.79 kg/ha for HD 3086 and HD 3059. Thus, it reduced the cost of seed which, in turn, increased farmers' net income. The state-wise scenario showed that enhanced rate of income of the farmers could be obtained for use of farm machinery. Alfares and Duffuaa method referred economic problem (aggregate wt. 1823.11) was the most serious issue for up-scaling and out-scaling of machinery. Majority of the farmers are resource-poor, Custom Hiring Centres (CHCs) should be established through Public Private Partnership (PPP), private entrepreneurs, co-operative basis, farmer's organizations and charitable trusts. Small and marginal farmers can also avail machinery from different state institutions which offer handsome subsidies on agricultural machinery procurement. Govt. guidelines towards designing of appropriate model of farm machineries should be made mandatory for access of small and marginal farmers. Further, for provision of credit facilities, Agriculture Machinery Banks can be a useful step support in direction. In addition, awareness and training programme will motivate the farmers for use of machineries which may contribute to the goal of doubling farmers' income by 2022-23. Increasing demand for farm machineries explores the opportunity for establishment of business models and entrepreneurial innovation. Besides, spill over effect of mechanization opens up the scope for development of animal husbandry, dairying, fisheries sector too. So it can be concluded that adoption of seed cum fertilizer drill and zero tillage had positive socio-agro-economic impact on small holder farmers' livelihood and the sustainability of this impact can be ensured through support of CHC, Government and rural financial institutions.

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Figures

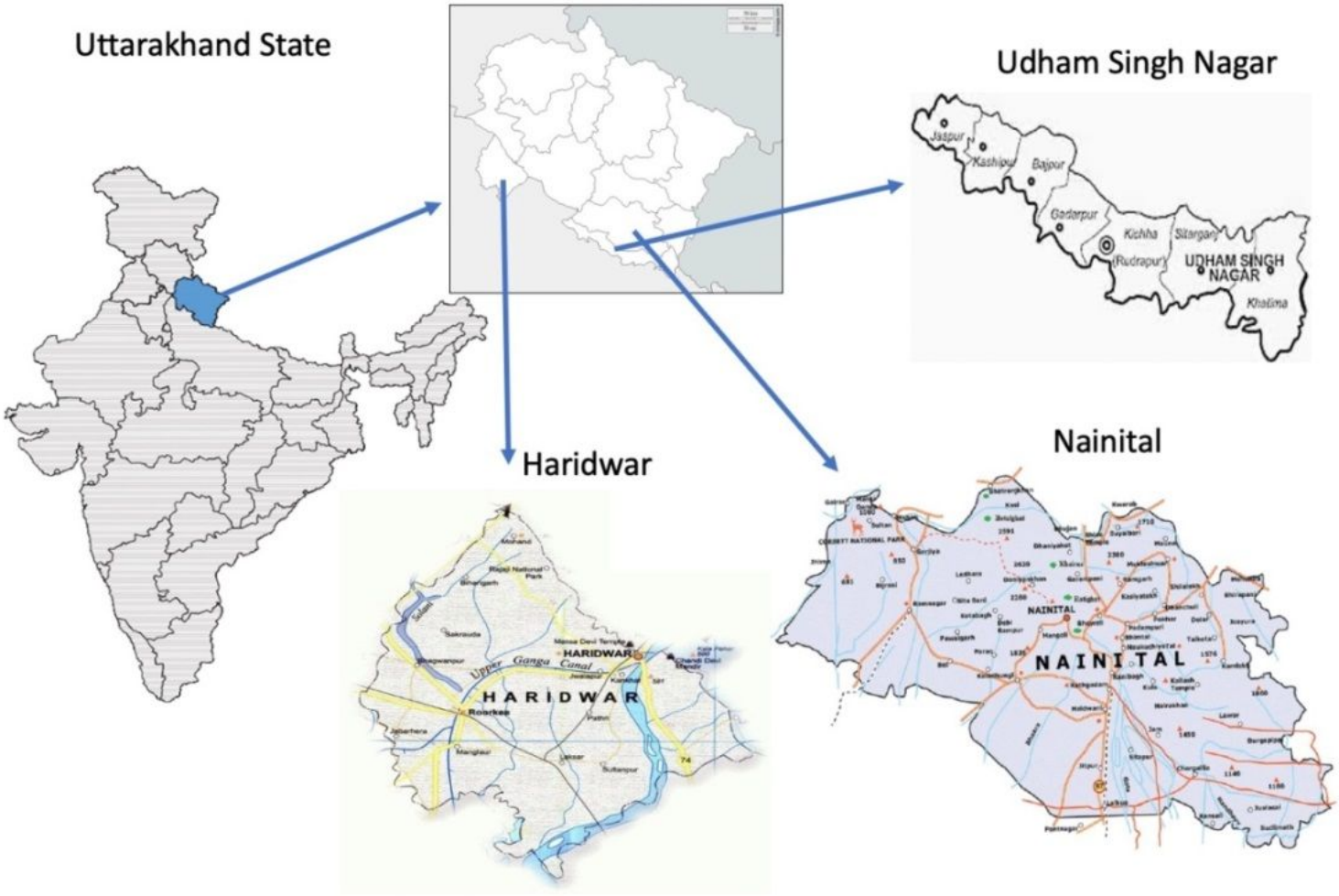

Figure 1

Locale of micro study area. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

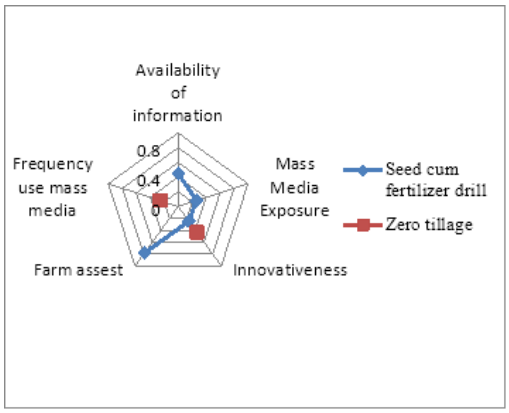

Figure 2

Kendall Tau estimation between farmer using Seed Cum Fertilizer Drill and Zero tillage and significant explanatory variables

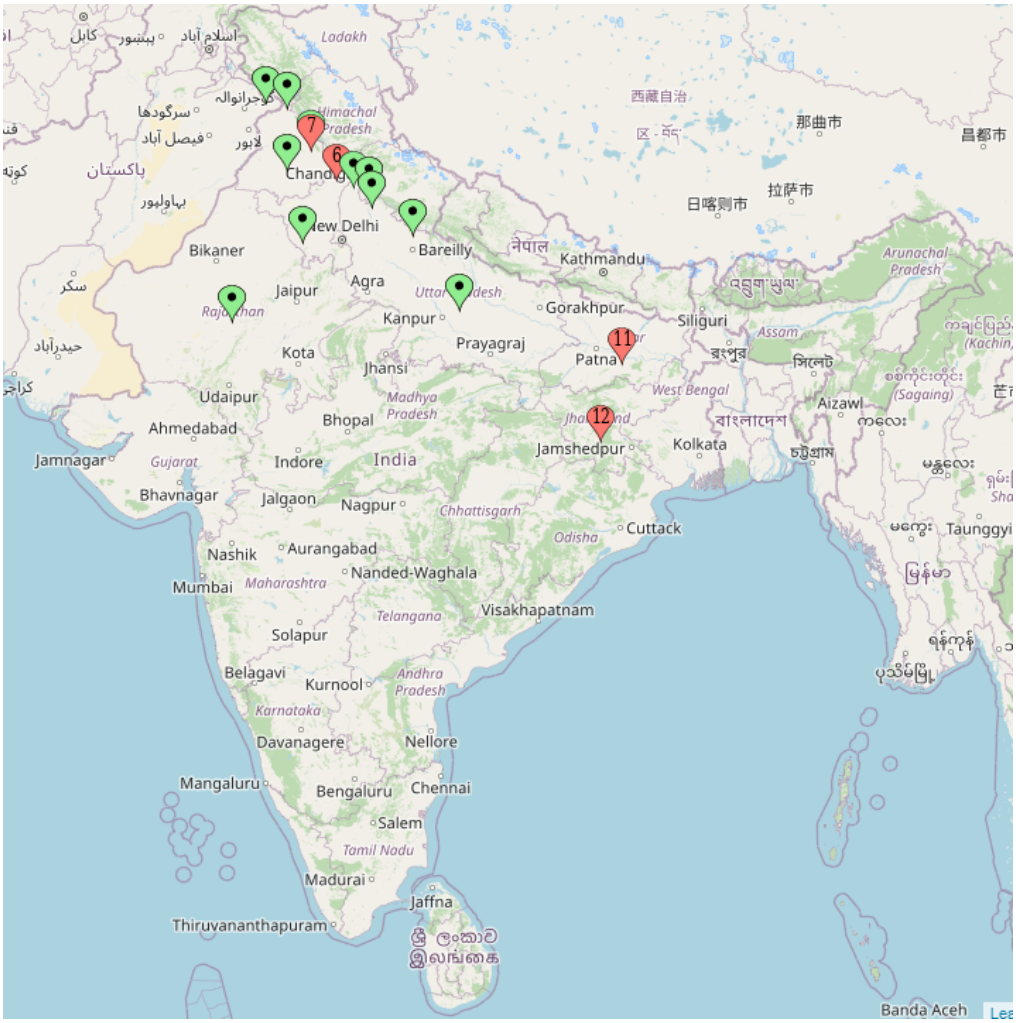

Figure 3

Agro ecological distribution of selected improved wheat varieties *Anonymous, 2020, http://www.icar iirr.org/AICRIP/Centers/43%20pantnagar.pdf **Anonymous, 2020, http://ztmbpd.iari.res.in/technologies/varietieshybrids/cereals/wheat/. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

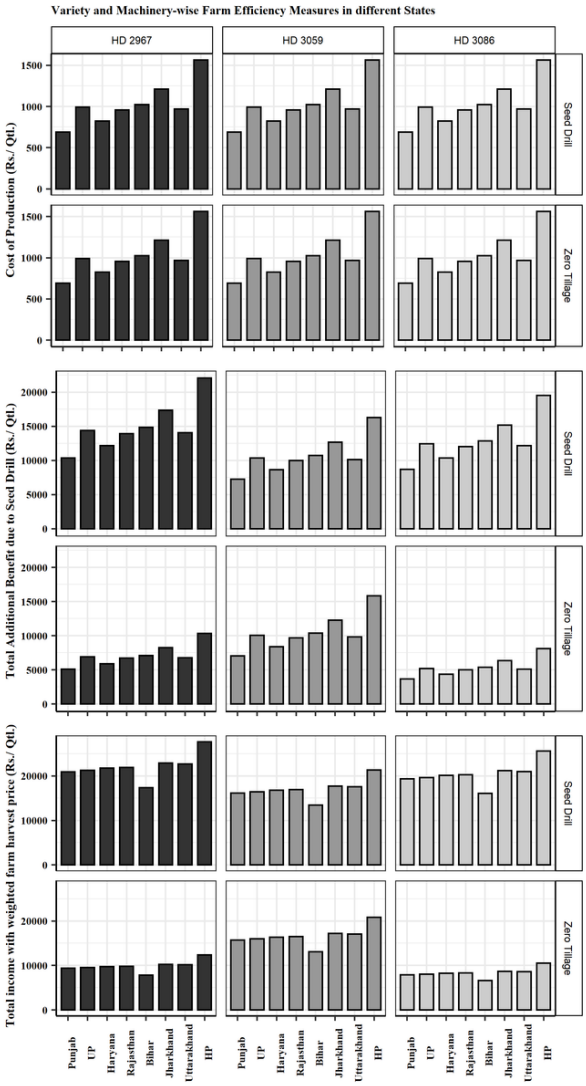

Figure 4

Wheat varieties and Machinery-wise (Seed cum Fertilizer Drill and Zero Tillage) Farm Efficiency Measures in different States

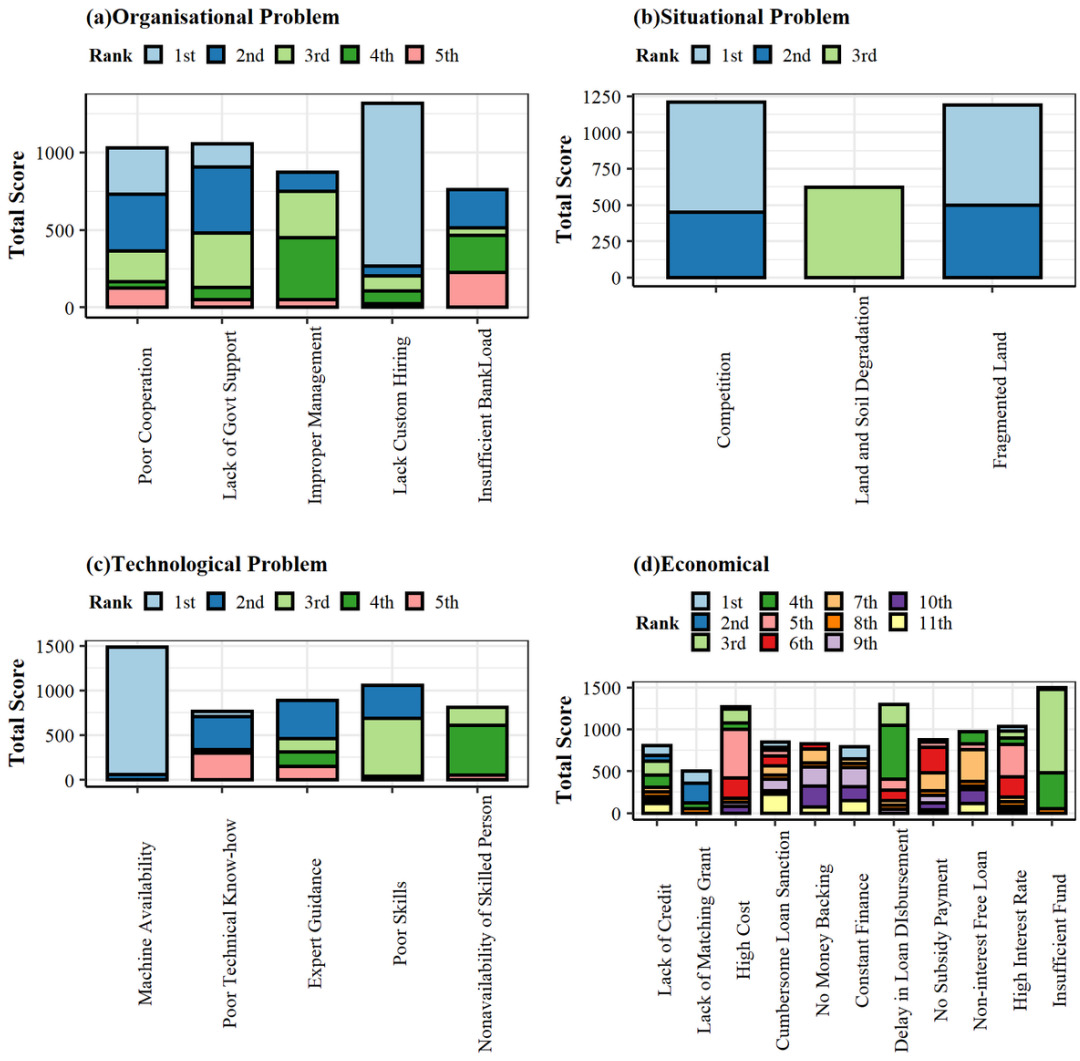

Figure 5

Constraints analysis for out scaling of machineries