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Resource Use Pattern and Efficiency of Wheat Production in Punjab

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Abstract

The farm level data collected under centrally sponsored scheme "Comprehensive Scheme for Studying the Cost of Cultivation of Principal Crops in Punjab" has been analyzed to examine the resource-use pattern and efficiency in wheat production in Punjab. The expenditure on machinery, fertilizers (NPK and other fertilizers and micronutrients) and human labour were the major cost components accounting for 40.46 per cent, 20.34 per cent and 17.41 per cent of total variable cost of cultivation of wheat on the overall farms. The farm size-wise analysis showed that total variable cost had inverse relationship with the farm size. The profitability in wheat, in terms of percent returns over variable cost on overall farms was about 70 per cent and its relation with farm size was observed to be direct with the highest on large farms (71.39%) followed by medium farm (69.92%) and small farms (66.37%). The results of Cobb-Douglas production function revealed that human labour, tractor use, irrigation, NPK fertilizers and other fertilizers were statistically significant and thus important factors in determining the wheat productivity in the state. Further, the study pointed out towards the excessive use of resources like human labour, irrigation, nitrogen and potash in wheat which needs to be reduced in order to increase the profitability of this crop.

Keywords: Resource use, Efficiency, Production function, Wheat production, Wheat productivity

JEL Classification: Q12, D61, C67

Introduction

The wheat and rice are the most important crops of country and remained the corner stone for national food security management. Due to favourable price and public procurement policy along with consistent efforts of agricultural scientists and extension workers, the production of wheat in India increased dramatically since the invent of green revolution during mid-1960s. Punjab, which is known as the "Granary of India" a major part of the total productive land is being used to produce food grain mainly comprising the wheat and rice. The total gross cropped area of Punjab was about 78 lakh ha, out of which about 85 per cent was covered under wheat and paddy during 2020-21. Punjab is important wheat producing state in the country with area and production of 35.30 lakh ha and 172 lakh tones during 2019-20 respectively. The productivity of wheat in Punjab was 4868 kg per ha (GoP 2021) which is more than the country's average of 3464 kg per ha (GoI, 2021).

The word called 'resource use efficiency in agriculture' generally defined to contain the concepts of technical efficiency, allocative efficiency, and environmental efficiency. A progressive farmer allocates the land, labour, water, and other resources in an optimal manner, so as to increase income, at optimum cost, by resource conservation. On the other hand, there are numerous studies screening that farmers often use their resources sub-optimally. Even as some farmers may achieve maximum physical yield per unit of land at a high cost, some others achieve maximum profit per unit of inputs used. The significant variations in the use of vital inputs resulted into large variations in wheat yield across farms in state (Singh *et al* 2012). The major determinants of wheat productivity were sowing time, irrigation, nitrogen application and expenditure on plant protection chemicals. In Punjab, agricultural inputs like family labour, tractor, electric motor, diesel engine, fertilizers and seeds had not been used efficiently over time in wheat crop (Singh *et al* 2016 and Narayanamoorthy *et al* 2017). In this backdrop, the present study has been undertaken to examine the resource use pattern and efficiency in wheat production in Punjab state.

Data Sources and Methodology

The farm level data collected under centrally sponsored scheme "Comprehensive Scheme for Studying the Cost of Cultivation of Principal Crops in Punjab" for year 2018-19 has been analyzed. The sampling design for this scheme

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being run in the Department of Economics and Sociology, PAU, Ludhiana consists of the three-stage stratified random sampling technique. To uniformly represent whole region, the state was divided into three agro-climatic zones based on soil type, irrigation, rainfall, crops grown etc. Different stages of sampling include tehsils, clusters of villages and operation holding within a cluster of villages. The scheme covered 300 farm holdings distributed among 30 tehsils representing different agro-climatic zones. The total number of household that cultivate wheat crop were 292. In present study, in order to examine the regional effect, the agro-climatic zones were reframed according to the classification provided by National Remote Sensing Centre. The farm size holdings included small (<2 ha), medium (2-6 ha) and large (>6 ha) farm households.

To study the resource productivity and resource use efficiency production function analysis was used. Based on the value of coefficient of multiple determination (R^2) and sign and significance of the coefficients following Cobb-Douglas production function has been finalized to identify the determinants of crop productivity.

$lnY_i = ln\beta_o + \beta_1 lnX_1 + \beta_2 lnX_2 + \ldots\ldots\ldots\ldots \beta_i lnX_i + lnu_i$ (Where i = 1,2,3…..n)

The variables defined in the model are as follows

Y = Main product of wheat (Qtls/ha), β_o = Constant, β_i = Estimated coefficient, u_i = Random error term, X1 = Crop area (Ha), X2 = Human labour (Man hours/ha), X3 = Tractor use (Hours/ha), X4 = Combine use (Hours/ha), X5 = Irrigation machine use (Hours/ha), X6 = Seed (Kg/ha), X7 = Nitrogen (Nutrient Kg/ha), X8 = Phosphorous (Nutrient Kg/ha), X9 = Potash (Nutrient Kg/ha), X10 = Farm yard manure (Qtls/ha), X11 = Other fertilizers (Kg/ha), X12 = Insecticides/Pesticides (Rs/ha), Z1 = Dummy variable for Zone I, Z2 = Dummy variable for Zone III, C2 = Dummy variable for medium farmers and C3 = Dummy variable for large farmers. To know the regional and farm size categories effect, dummy variables were used. The dummy variable for Zone II was taken as base variable and to see the regional effect while in case of farm size category the dummy variable for small farmers was used as base variable.

The allocative efficiency (AE) of each input was calculated from the β's obtained from multiple regression as following:

$AE = MVP_i / MFC_i$

Where,

MVP_i = Marginal value productivity of the i^{th} input

MFC_i = Marginal factor cost of the i^{th} input

$$MVP_i = \beta_i \frac{\overline{Y}}{\overline{X}_i} \times P_y$$

Where,

β_i = Estimated coefficient or elasticity of the i^{th} input

$\overline{Y}$ = Geometric mean of output

$\overline{X}_i$ = Geometric mean of i^{th} input

P_y = Price of output

Results and Discussion

The use of various inputs like seed, labour (human, animal and machinery), irrigation, fertilizers, plant protection, chemical etc. transform into the crop output. Thus, it is important to know the extent of use of important inputs in crop production. Equally important is the knowledge of cost structure indicated by the share of various input factors in the cost of cultivation. For determining the profitability of wheat, the cost structure of various size categories of farms along with total variable costs, cost A1, cost A2 and cost A2+FL has been worked out and has been discussed.

Resource use pattern

Wheat being the main *rabi* crop accounted for about 44 per cent of the gross cropped area on overall sample farms during 2018-19 in Punjab. The resource use pattern which included the physical quantities of different inputs used in the cultivation and output of wheat crop has been displayed in Table 1.

Seed being the basic farm input, it was observed that the quantity of seed use on overall farms was 114.14 kg per ha which was more than the recommended dose of 100 kg per ha (PoP 2022). The average use of nitrogen and phosphorous was more than the recommended dose while that of potash was lower. The use of fertilizers as well as of seed did not varied much with the change in farm size category. The use of farm yard manure was more on small farms as compared to the large farms reason being the higher per ha availability of manure on small farms as compared to large farms. The total per ha human labour use in wheat cultivation on overall farms was 107.97 man-hours. The use of total human labour decreased with the increase in farm size category and in comparison of 130 man-hours on small farms, the large farms used only 102.48 man-hours. On small farms the use of family labour was more than their counterparts while the case was reverse in hired human labour. This was due to the reason that small farms had relatively higher own work force in relation to their land, whereas on account of large size of farms the large farmers have to depend more on the hired labour.

The use of animal labour has almost been negligible in Punjab agriculture as the machines have replaced them. Wheat crop is one of the crops where agricultural machinery is used extensively, be in sowing, spraying or harvesting. Overall, the tractor was used for 13.15 hours per ha in wheat crop and its use was almost same for all farm size categories.

Though, the small farms have less of the owned machinery but they use it in agronomic practices by hiring from others. The use of owned tractor increased with increase in farm size while that of hired decreased with the increase in farm size. The harvesting of wheat is mostly done by combine harvesters and on overall farms it was used for 1.41 hours per ha with 0.07 owned and 1.34 hired combine harvester hours. Power sprayer used for spraying of plant protection chemicals was 2.21 hours.

The use of power sprayer is less on small farms as compared to the large farms as on small farms due to smaller area, spraying was done manually also. The overall yield of wheat crop was 49.36 qtls per ha with 49.12 qtls per ha on small, 49.24 qtls per ha on medium and 50.05 qtls per ha for the large farms. The direct relation of farm size and productivity though not very strong, has also been backed by Das (2021). The yield of by-product was 34.97 quintals per hectare which is wheat straw and used as dry fodder for livestock. The category-wise output of wheat by-product showed a weak inverse relationship with farm size. This was due to the fact that small size farms harvest and more by-product to meet the livestock requirement.

Structure of cost of cultivation

The structure of cost of cultivation of wheat crop presented in Table 2 showed that overall per ha variable cost on input use was Rs 29862. The per ha average cost in respect of machine use, fertilizers (NPK and other fertilizers and micronutrients) and human labour, was worked out to be Rs 12082, Rs 6074 and Rs 5200 with respective share in total variable cost of cultivation at 40.46 per cent, 20.34 per cent and 17.41 per cent. While the family labour (Rs 2643/ ha) and hired labour (Rs 2556/ha) accounted almost equally

Table 1 Resource use pattern in wheat cultivation, Punjab, 2018-19 **(Per ha)**

Sr. No.	Particulars	Small	Medium	Large	Overall
A	**Inputs**				
1	Seed (kg)	116.11	113.96	113.77	114.14
2	Fertilizers and manures				
	Nitrogen (kg)	171.40	174.62	177.72	175.59
	Phosphorous (kg)	66.29	64.43	67.80	66.12
	Potash (kg)	1.38	2.16	2.73	2.32
	Other fertilizers and micronutrients (kg)	1.87	1.43	1.68	1.59
	Farm yard manure (qtls)	6.04	4.73	0.30	2.96
3	Plant protection chemicals (kg)	1.53	1.44	1.48	1.47
4	Human labour (man-hours)	130.00	107.41	102.48	107.97
	i) Family	79.50	58.02	46.93	55.76
	ii) Hired	50.50	49.39	55.55	52.21
5	Animal labour (hours)	0.55	0.24	0.14	0.23
6	Tractor (hours)	13.26	13.36	12.92	13.15
	i) Owned	4.99	9.51	9.87	9.12
	ii) Hired	8.27	3.85	3.05	4.03
7	Combine harvester (hours)	1.47	1.40	1.40	1.41
	i) Owned	0.10	0.04	0.09	0.07
	ii) Hired	1.37	1.36	1.31	1.34
8	Power sprayer (hours)	1.88	2.40	2.12	2.21
	i) Owned	0.88	1.35	1.36	1.30
	ii) Hired	1.00	1.05	0.76	0.91
9	Irrigation machinery (hours)	31.83	31.55	29.45	30.67
B	**Output**				
1	Main product (qtls)	49.12	49.24	50.05	49.36
2	By-product (qtls)	35.96	34.48	34.04	34.97

in total variable cost, the share of hired machine labour (Rs 7440/ha) in total variable cost of wheat cultivation was estimated to be more than 1.5 times as compared to that of the own machine charges (Rs 4642/ha). The other items of cost like plant protection chemicals, seed and interest on working capital accounted for 6.94 per cent, 8.92 per cent and 3.03 per cent of the total variable cost.

Irrigation, one of the most important inputs accounted for only 2.45 per cent of the variable cost, the reason being free of cost supply of power to farmers in the state and most of the wheat crop is irrigated through electric/submersible pumpsets. The various costs like cost A1, cost A2 and cost A2+FL came out to be Rs 28179, Rs 34127 and Rs 36770 per ha respectively on the overall farms.

The farm size-wise analysis showed that total variable cost has a declining trend with the increase in the farm size. It was worked out to be about Rs 33441, Rs 29877 and Rs 28816 on small, medium and large farms respectively. The reasons for high variable cost on small size farms was the economies of scale observed in the input use in wheat cultivation particularly in case of human labour and machine charges showing a strong inverse relationship with the farm size. The cost A1 showed clear declining trend with the increase in farm size while the rental value of leased-in land showed positive trend. Both cost A2 and cost A2+FL had not shown clear relationship with the farm size.

In percentage terms, the cost of family labour decreased while that of hired labour increased with the increase in farm size category. Similarly, the overall value of machine labour had a tendency to decrease with the increase in farm size, both in absolute as well as percentage terms. Further, amongst the components of machine charges, while the owned machine charges showed strong direct relationship with the farm size, the value of hired machine labour revealed a strong inverse relationship with the farm size. The per hectare value of seed, irrigation, FYM and interest on working capital were the other cost items which have shown an inverse relationship with the farm size. On the other hand, expenditure on NPK and other fertilizers in percentage terms had an increasing association with the farm size. However, no clear trend was observed in case of per hectare expenditure on account of plant protection chemicals and the farm size.

Returns

The cost on inputs used, are borne by the farmers for the profits they want to earn from the crop cultivation. The profitability per hectare for wheat crop displayed in Table 3 showed that the value of main product and by-product taken together as gross returns turns out to be Rs 99653 on the overall farms and Rs 99442, Rs 99325 and Rs 100722 on small, medium and large farms respectively. The reason for high gross returns was due to slightly higher productivity on the large farms as compared to other counterparts. The returns over variable cost were calculated by deducting the variable costs from the gross returns which was Rs 69791 for the overall farmers with Rs 66002, Rs 69447 and Rs 71905 on small, medium and large farms respectively. The percent returns over variable cost was the maximum on large farms with 71.39 per cent followed by medium farm with 69.92 per cent and 66.37 per cent on small farms. Further, the returns over cost A2+FL were Rs 60230 on small, Rs 62983 for medium and Rs 64209 on the large farms and the overall returns were Rs 62883 per ha. The percent returns over cost A2+ FL also increased with increase in the farm size category. The study clearly revealed that the farm size turned out to be an important factor in determining the profitability and overall efficiency of wheat production in Punjab.

Production function analysis

The cost-return analysis discussed in the previous section provides only rough or general indication of cost structure and does not throw sufficient light on the efficiency of resource allocation. However, one of the main objectives in production activity is to coordinate and utilize the resources in optimal way to maximize the returns/yields. Thus, production function analysis was used to determine the functional relationship of various inputs used in production with the wheat output level.

The results of estimated Cobb-Douglas production function on data of wheat crop for the year 2018-19 are presented in the Table 4. The value of the coefficient of multiple determination (R^2) was 0.35 which signifies that the included independent variables explained 35 per cent of the variations in the dependent variable (productivity). The estimated coefficient with respect to quantity of nitrogen was positive and significant at one per cent level. The value of the coefficient (0.292) indicated that with one percent increase in the use of nitrogen, the yield of wheat would increase by 0.292 per cent. The other variable that was positively significant at one per cent level of significance was potash with the magnitude of 0.024. The wheat production elasticity with respect to the use of phosphorous and other fertilizers was found to be negative and significant, thus indicating the excessive use of respective inputs. The use of machinery was represented by the use of tractors. It was found to have positive and significant effect at 5 per cent level. The wheat production elasticity with respect to human labour hours was significant at 10 per cent level of significance with magnitude of 0.121. Similar positive and significant relationship between wheat productivity and human labour use was also observed by Kaur *et al* (2013) and Ahmad *et al* (2018). The value of coefficient (0.022) for irrigation was positively significant at one percent level significance which indicated that with one percent increase in irrigation the productivity of wheat would increase by 0.022 per cent. Seed was found to be statistically non-significant in wheat and similar results were found by Yadav *et al* (2022). The impact of agro-

Table 2 Cost structure of wheat crop, Punjab, 2018-19 **(Rs/ha)**

Sr. No.	Particulars	Small	Medium	Large	Overall
1	Seed	2737.66 (8.19)	2667.200 (8.93)	2638.07 (9.15)	2663 (8.92)
2	Fertilizers and manures	6070.10 (18.15)	6044.38 (20.23)	6224.86 (21.60)	6126.00 (20.52)
	NPK	5839.11 (17.46)	5807.30 (19.44)	6034.09 (20.94)	5910.00 (19.79)
	Other fertilizers and micronutrients	126.21 (0.38)	152.37 (0.51)	185.68 (0.64)	164.00 (0.55)
	Farm yard manure	104.78 (0.31)	84.71 (0.28)	5.09 (0.02)	52.00 (0.18)
3	Plant protection chemicals	2097.67 (6.27)	1935.97 (6.48)	2204.58 (7.65)	2073.00 (6.94)
4	Human labour	6260.58 (18.72)	5303.09 (17.75)	4859.13 (16.86)	5199.77 (17.41)
	i) Family	3690.83 (11.04)	2833.05 (9.48)	2204.43 (7.65)	2643.38 (8.85)
	ii) Hired	2569.75 (7.68)	2470.03 (8.27)	2654.71 (9.21)	2556.39 (8.56)
5	Animal labour	65.52 (0.20)	29.00 (0.10)	16.24 (0.06)	28.00 (0.09)
6	Machine labour	13854.50 (41.43)	12253.64 (41.01)	11317.51 (39.27)	12082.00 (40.46)
	i) Owned	2859.82 (8.55)	4870.47 (16.30)	4795.82 (16.64)	4642.00 (15.55)
	ii) Hired	10994.68 (32.88)	7383.17 (24.71)	6521.69 (22.63)	7440.00 (24.91)
7	Irrigation	1288.97 (3.85)	670.81 (2.25)	645.59 (2.24)	733.00 (2.45)
8	Miscellaneous expenses	52.43 (0.16)	67.90 (0.23)	37.08 (0.13)	53.00 (0.18)
9	Interest on working capital	1013.36 (3.03)	905.37 (3.03)	873.22 (3.03)	905.00 (3.03)
	Total variable cost	33440.79 (100.00)	29877.35 (100.00)	28816.29 (100.00)	29862.27 (100.00)
	Cost A1	30966.07	28158.14	27358.86	28178.66
	Rental value of leased-in land	4556.00	5351.00	6949.00	5948.00
	Cost A2	35522.07	33509.14	34307.86	34126.66
	Cost A2 + FL	39212.90	36342.19	36512.29	36770.04

Figures in parentheses are percentage to total variable cost

climatic regions explained by dummy variables for zone I was negative but significant, which means that on account of regional differences the yield in zone I was significantly less as compared to Zone II. On the other hand, positive and significant value of regional dummy of Zone III indicated that due to regional differences the productivity in Zone III was significantly higher as compared to that of Zone II. Across different farm size categories, there was no significant difference between the yields of these categories as the coefficient was non-significant.

Table 3 Returns of wheat crop cultivation, Punjab, 2018-19 **(Rs/ha)**

Particular	Small	Medium	Large	Overall
Main-product	90344	90568	92060	90781
By-product	9098	8756	8661	8872
Gross returns	99442	99325	100722	99653
Returns over variable cost	66002	69447	71905	69791
Percent returns over variable cost	66.37	69.92	71.39	70.03
Returns over cost A2+FL	60230	62983	64209	62883
Percent returns over cost A2+FL	60.57	63.41	63.75	63.10

Resource Use Efficiency

The resource use efficiency in respect of input factors which significantly affect the wheat productivity has been worked out and presented in Table 5. The magnitude of ratio of MVP and MFP of human labour in wheat crop was 2.00 which was significantly different from unity indicated that there was under-utilization of human resource in wheat crop. This means that with one rupee additional expenditure on this resource, returns would have appreciated by Rs 2.0. The ratio of MVP and MFP of irrigation (1.95) indicated that there was under-utilization of irrigation in wheat crop and with one-rupee additional expenditure on this resource, returns would have appreciated the returns by Rs 1.95. The under-utilization of irrigation water in wheat crop was also observed by Singh *et al* (2020). MVP and MFC ratio of more than unity in case of irrigation, nitrogen and potash (1.95, 9.83 and 5.07 respectively) point towards under-use of these resources in wheat production. The ratio of MVP to MFC for tractor use was not significantly different from unity and thus, its was optimal in wheat production. Significantly less than unity ratio w.r.t. phosphorous (-0.50) and other fertilizers (-2.88) shows that use of these inputs should be decreased in order to achieve higher returns.

Table 4 The coefficients of production function (Cobb-Douglas) for wheat crop, Punjab, 2018-19

Variables	Coefficients	Standard error
Intercept	0.115	0.370
Area under wheat (Ha)	-0.008	0.040
Human labour (Man hours/ha)	0.121*	0.061
Tractor use (Hours/ha)	0.127**	0.059
Irrigation machine (Hours/ha)	0.022**	0.009
Seed (Kg/ha)	0.245	0.159
Nitrogen (Nutrient Kg/ha)	0.292***	0.084
Phosphorous (Nutrient Kg/ha)	-0.014***	0.005
Potash (Nutrient Kg/ha)	0.024***	0.009
Other fertilizers (Rs/ha)	-0.013***	0.004
Plant protection chemicals (Rs/ha)	0.008	0.019
Z1 (Dummy for zone I)	-0.149***	0.024
Z3 (Dummy for zone III)	0.063***	0.019
C2 (Dummy for medium category)	0.027	0.028
C3 (Dummy for large category)	0.034	0.039
R^2	0.35	
Adjusted R^2	0.32	
Number of observations	292	

*Note: ***,** and * denotes significance level at 1 per cent, 5 per cent and 10 per cent respectively*

Table 5 Resource use efficiency (Allocative efficiency) in production of wheat, Punjab, 2018-19

Variable	Coefficient	MVP	MFC	Allocative Efficiency MVP/MFC	Remarks
Wheat					
Human labour (man-hours/ha)	0.121	94.97	47.41	2.00	Under-utilization
Tractor use (hours/ha)	0.126	881.43	836.87	1.05^{NS}	Optimum utilization
Irrigation machine (hours/ha)	0.021	122.19	62.73	1.95	Under-utilization
Nitrogen (nutrient kg/ha)	0.292	169.90	17.28	9.83	Under-utilization
Phosphorous (nutrient kg/ha)	-0.014	-21.42	42.54	-0.50	Over-utilization
Potash (nutrient kg/ha)	0.024	136.46	26.9	5.07	Under-utilization
Other fertilizers	-0.013	-2.87	1	-2.88	Over-utilization

NS: Non-significant

Conclusions and Policy Implications

The major cost components in wheat cultivation were machine use, fertilizers and human labour and these constituted 40.46 per cent, 20.34 per cent and 17.41 per cent of the total variable cost (Rs 29862/ha). The total variable cost has a declining trend with the increase in the farm size. The per ha gross returns came out to be Rs 99653 which was about 70 per cent of the variable cost. The profitability of wheat cultivation revealed a direct association with the farm size and thus, increased with the increase in farm size. The production function analysis revealed that use of human labour, tractor, irrigation machinery, nitrogen, phosphorus, potash and other fertilizers had the significant impact on wheat productivity in the Punjab State. While the use of human labour, irrigation, nitrogen and potash in wheat cultivation was less than optimal; use of phosphorus and other fertilizers was observed to be excessive. The technological and policy interventions aimed at economising the use of human labour and machinery which will have a significant impact to arrest the escalating cost of cultivation of wheat crop in state. Determining the optimal combinations of human labour and type/size of machinery and its promotion is the need of hour. The results suggest the need for policies aimed to bring down the cultivation costs especially on the smaller size farms. Machinery being the major component of variable costs, the government should develop the PACS as Agro-Service Centres for such services and take steps like fixing the reasonable custom hiring rates along with priority availability for small farmers. This would be helpful to small farmers in lowering their machinery and labour costs, hence increasing the net incomes. The irrational use of some of important resources in wheat cultivation needs to be addressed seriously. This calls for strengthening of the extension infrastructure to sensitize the farmers to make the judicious use of vital resources and bring down the cost of cultivation.

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