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SOCIOECONOMICS AND AGRONOMY OF WHEAT YIELD IN COTTON-WHEAT PUNJAB (PAKISTAN): A QUALITY-QUANTITY ASSESSMENT

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ABSTRACT

Pakistan is the 8th largest wheat producer in the world. However, the country's wheat productivity is not as impressive as that of China, India and Bangladesh. Punjab shares more than 70 percent of the country's total area cultivated under wheat crop. Although the application of farm inputs in their optimal quantities translate into improved wheat yield, however the qualitative attributes of the agronomy applied to wheat production as well as the socioeconomic realities of the wheat growers also matter for better output. Keeping in view the role of wheat as a staple diet in Pakistan along with its strong backward and forward linkages with the industrial sector of the country, the study investigated the impact of socioeconomic and agronomic settings on wheat yield in wheat-cotton Punjab (Pakistan). District Bahawalnagar stands first regarding its share in the total acreage of agricultural land sown under wheat crop as well as its share in total wheat production in Punjab. By surveying the selected villages of the district, 120 wheat growers were contacted for the collection of data through a questionnaire. The information was recorded through face-to-face interviewing, while data was analyzed by using SPSS® version 20. Amongst the socioeconomic attributes, a farmer's educational status as literate and landownership status as landless were observed to be positively related to the wheat yield. While amongst the agronomic practices, seed sowing through broadcast method, manual wheat harvesting, poor soil fertility, and the tube-well as the only mode of irrigation were negatively associated with the wheat grain yield. The study concludes that in the context of wheat-cotton Punjab, qualitative attributes of the wheat growers and that of agronomic practices matter in determining wheat yield. The study suggests the need for rural infrastructure (especially, human and irrigational) development in order to bridge the actual and potential yield gaps for wheat crop.

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INTRODUCTION

Globally, by contributing about 1/5th of man's daily calories and protein intake, wheat stands as the main source of today's human diet (Shiferaw *et al.*, 2013). For the year 2019, globally, the area sown under wheat crop was recorded as 220.11 million hectares with 765.41million tons grains production, and with an average yield of 3405 kg grain per hectare (FAOSTAT, 2019).

Wheat is amongst the major crops of Pakistan. Being the staple food of Pakistan, wheat production has pivotal role in securing dietary requirements of the country's ever-increasing population. As population growth is one of the major factors of demand for more wheat production while different kinds of factors contribute to the yield. With a current annual population growth rate of 2.4 percent (Pakistan Bureau of Statistics, 2017), Pakistan's population is expected to exceed 300 million by the year 2050 (United Nations, 2015) and that situation would demand huge quantity of wheat grain to feed the population. Though in the last 10 years per hectare yield of wheat has shown an average growth of 234 kg yet this modest average increase in productivity is incompatible with the large increase in population (FAO, 2019).

For the year 2017-18, wheat production accounted for 9.1 percent of total value added in agriculture and that of 1.7 percent in the GDP of Pakistan. For the same period, recording a decline of 4.4 percent over the production recorded last year, wheat production stood at 25.492 million tonnes (Government of Pakistan, 2018). Nearly 80 percent of farmers were growing wheat on an area of around 8.95 million hectares (about 40 percent of the country's total cultivated land) during the winter (Rabi) season of which 6.62-million-hectare area (73.9%) was put under wheat cultivation in the Punjab province (United States Department of Agriculture, 2018). According to the FAO (2018), with an annual per capita consumption of 124.4 kg, Pakistan is amongst the world's foremost consumers of wheat. Moreover, with an average annual production of 25 million tons wheat the country ranks 8th in the wheat producing countries of the world (FAO, 2018). However, the country's wheat productivity is not that impressive, as according to FAOSTAT (2017) Pakistan's per hectare wheat yield in 2016 remained 2844 kg, as against 5408 kg, 3093 kg, and 3029 kg respectively for China, India and Bangladesh's for the same year.

Development of new and improved varieties of wheat have led to far higher yields per hectare but many other factors, like soil fertility status, sufficient irrigation water, farmers' expertise and knowledge, pre- and post-harvest care, adequate availability, and use of modern technology have also impact on the average national wheat yield and are the basic elements required to make Pakistan self-sufficient in wheat (Tadele, 2017).

Predominantly agriculture-relying and rural-livelihood context of nearly 65% of Pakistan's population, brings to the fore the need for adoption of modern farming practices and provision of quality farm inputs to the farming community at affordable cost to enable Pakistan achieve per acre yield to levels already achieved by many other countries. Improved irrigation system, rural infrastructure development, farmers' education and training to familiarize them with modern agricultural practices are required along with concerted efforts and scientific approach to achieve self-sufficiency in food. In addition, the factors like, well-levelled and weedless fields, high yielding wheat varieties, timely sowing and application of fertilizers and pesticides, will improve the wheat yield. Attention must be given to avoid pre- and post-harvest losses through proper threshing, storage, and preservation (Alam, 2001).

Laser land levelling—by using a laser-equipped drag bucket—provides a more precise and rigorous land levelling technique (Ali, et al., 2018). Also, through laser land levelling, the levelled farm fields can enhance irrigation and fertilizer use efficiency and can stop soil nutrient losses (through enhanced runoff control), hence resulting into higher crop yields (Jat *et al.*, 2009; Jat *et al.*, 2011). Moreover, laser land levelling can also increase yields through better crop germination and crop stands (Mallappa and Radder, 1993; Ren *et al.*, 2003). Several studies, Das *et al.* (2018); Jat *et al.* (2003); Jat *et al.* (2006);Hoque and Hannan (2015);Naresh *et al.* (2014) have confirmed an increased grain yield of wheat in laser levelled field as compared to yield of non-laser levelled field.

As compared to broadcast planting, linear planting method has been found helpful in generating more wheat grain yield by precisely adjusting the distance and depth regarding proper positioning of seeds and other relevant characteristics of performance (Limochi *et al.*, 2014). Similarly, in contrast with broadcast sowing, wheat sowing under bed planting has shown better results for yield contributing parameters (plant height, numbers of tillers, number of grains per spike, 1000 grain weight, and grain yield) of wheat crop; bed planting of wheat produced 13% more yield and also showed higher benefit cost ratio for Punjab, Pakistan (Chauhdary *et al.*, 2016).

Method of fertilizer application may influence the degree of responsiveness of crop in terms of yield. Application of phosphatic fertilizer by fertigation along with selection of an appropriate variety may contribute to improve fertilizer efficiency and increase wheat grain yield. As contrary to broadcast method, phosphorus fertilizer application through fertigation has produced higher yield responses in a region of Punjab-Pakistan (Alam *et al.*, 2003). In another field experiment, contrary to the broadcast method, the application of phosphorus with side dressing at planting was found to be increased wheat grain yield and other yield contributing parameters (Ali *et al.*, 2014).

The use of farmyard manure as soil organic amendment is of an economic and environmental interest. The effectiveness of soil organic amendment's application and its impact on wheat growth was assessed on agricultural soil under Tunisian arid climate. Wheat grain yield was observed to be enhanced with all amendments including farmyard manure (Cherif *et al.*, 2009). A field experiment was conducted to investigate the influences of different organic materials (including farmyard manure) on a site situated in south west of Iran. The effectiveness of farmyard manure on improving wheat grain yield was 14% over the control plots (Barzegar *et al.*, 2002). Yield relationship with soil organic matter fractions in soybean–wheat cropping system under long-term (30 years) fertilizer use were understood by Manna *et al.* (2007) at an experimental site in Ranchi, India. As compared to other treatments and untreated (control) plots, wheat grain yield was observed to be increased with the passage of time for NPK plus farmyard manure and for NPK plus lime.

Harvesting of wheat through different techniques, (like, manually, by using reaper, and through combine harvester) have considerable impact on wheat grain losses. For wheat crop, the grain losses with harvesting through reaper plus machine threshing and manual harvesting plus machine threshing at the field level have been observed to be 142.93 kg ha^{-1} and 164.37 kg ha^{-1} and accounting for 2.76% and 3.16%, respectively of wheat grain yield (Sattar *et al.*, 2015).

For the adoption of improved cereal cultivars, a management revolution is emerging as a fourth phase, in which knowledge and management substitute for material inputs (Dixon *et al.*, 2008), for which improved varieties will still be required.

Mostly in Punjab, the quality of underground water is brackish, hence not suitable for irrigating the crops for longer periods. A sustained application of underground water to the field crops would deteriorate the quality of the soil that would ultimately result into a permanent deterioration of a previously health natural resource. It is evident from a study (Tahir *et al.*, 2003) as compared to the other source of irrigation the canal water irrigation increases the potassium uptake and yield outcomes of wheat and oat crops.

While going through the literature it is evident that qualitative attributes of the wheat growers as well as the quality of wheat production technology used translate into better wheat yield. Hence, the current study intends to empirically investigate the quantitative response of wheat yield to the farm input quality as well as to farmer's social and economic characteristics in the context of cotton-wheat Punjab. To the best of our knowledge, previously there is not been a single study taking into account the impact of qualitative agronomic and socioeconomic attributes on the wheat yield. Also, most of the previous studies are experimental in nature; investigating only the impact of a particular application or treatment on crop yield. The current study is unique in the context that with its specific focus on the qualitative nature of the farm inputs it attempts to accurately specify an input-output model by incorporating the qualitative attributes of land, labor, and capital engaged in wheat production.

After presenting the regional and theoretical context of the study the following section presents information about data and methodology followed by the results and discussion section. In the last, the final section wraps up the whole discussion and puts forward the policy suggestions.

METHODOLOGY

The Terrain

The region of Punjab has diversification in terms of its agro-climatic characteristics. So, on the bases of different soil characteristics, varying weather conditions (temperature, rainfall), and availability or non-availability of water for irrigation purposes, Punjab has been classified into 5 sub-regions (see Figure 2) or crop zones namely, rice-wheat, cotton-wheat, mixed-crop, low intensity, and rain-fed zones (Amjad *et al.*, 2008). Our targeted area—Bahawalnagar district—is geographically situated in the southern part of the Punjab but in its agro-climatic context the district is included in the cotton-wheat zone. Out of total 36 districts of Punjab, Bahawalnagar district stands first regarding its share in total acreage of agricultural land sown under wheat crop and its share in total wheat production in Punjab (Government of Punjab, 2015).

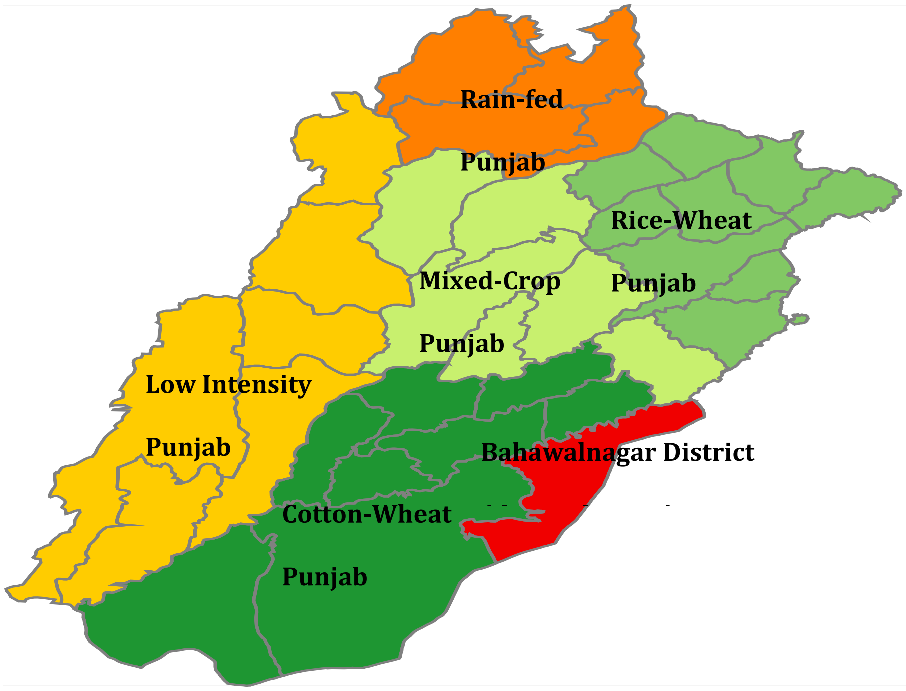

Figure 1. Agro-climatic zones of Punjab and the study area (Created by using Philcarto: cartographic software).

While talking about the impoverished situation of the district in terms of rural infrastructure (physical and human) provision, it stands 23rd out of total 36 districts of Punjab (Jamal *et al.*, 2003). This situation shows a highly impoverished status of Bahawalnagar district regarding rural infrastructure provision in comparison with other districts of the province. The lower rank order of the district coupled with poor socio-economic status of the farmers further worsen the situation when a large number of wheat growers are having less than 5 acres of own agricultural land for cultivation and a considerable number of landless farmers are cultivating wheat as a sharecropper, tenant, and or by renting-in land. Demographically, nearly 81% of the total population of district Bahawalnagar is residing in the rural areas (Government of Punjab, 2015). So, with a lion's share of rural population, the district has a wide rural-urban population gap as well.

Data Collection

A multi-stage sampling technique was employed for the present study. At first stage, amongst the five sub-districts of Bahawalnagar district, Bahawalnagar sub-district was chosen due to its status as tehsil head quarter.

Secondly, four agricultural areas surrounding Bahawalnagar city were randomly selected. The criterion to select the areas were their nature as purely rural as well as peri-urban. A brief description of each area is given below in the Table 1.

Table 1. Sample distribution

Areas	Distance from City	Location from City	Classified as	Sub-sample
1) Fateh Kot	13 Km	East	Rural Area	30
2) Mari Mian Sahib	10 Km	North	Rural Area	30
3) Rojhan Wali	05 Km	North	Peri-urban Area	30
4) Garhkana	03 Km	North East	Peri-urban Area	30
Total Sample				120

Thirdly, an equal sample of 30 wheat growers was allocated to and collected from each of the target areas. Finally, wheat growers/ farmers were targeted through simple random sampling technique. Hence, by surveying the four areas of Bahawalnagar sub-district, a cross section of 120 wheat growers was contacted for the collection of data. A questionnaire was developed and in order to check its validity and reliability, before final data collection, pretested on 10 wheat growers. The deficiencies pointed out during pre-testing were improved in the final document of the questionnaire. The information was recorded through face-to-face interviewing. The collected information was processed and analyzed by making use of SPSS software.

Econometric Estimation

For estimation of wheat yield as an outcome of the socioeconomic and agronomic variables, a multiple linear regression model was specified the generalized form of which is given below:

$$WY = \beta_O + \beta_1 LIT + \beta_2 LOS + \beta_3 SFS + \beta_4 SOI + \beta_5 LLS + \beta_6 WVS + \beta_7 SSM + \beta_8 FAM + \beta_9 AFS + \beta_{10} MOH + \epsilon_T$$

Where, WY represents the quantity of wheat yield as a dependent variable, X1 to 10denote the socioeconomic and agronomic variables as explanatory variables, β0 refers to the intercept coefficient, β1 to 10represent the partial regression coefficients of the explanatory variables, and ϵT stands for error term. The description of the variables is given in the Table 2.

Table 2. Description of the variables' names, types, and codes assigned to binary attributes.

Dependent Variable: WY: wheat yield (measured in mounds per acre)		
Type of Variables	Names of Variables	Qualitative Attributes of Variables
Socioeconomic Variables	LIT: farmer's literacy	illiterate = 0 literate = 1
	LOS: land ownership status	having no land ownership = 0 having land ownership = 1
Agronomic Variables	SFS: fertility status of soil	poor or average = 0 good = 1
	SOI: source of irrigation	tube well only = 0 canal and tube well = 1
	LLS: laser leveling status of land	conventionally leveled = 0 laser leveled = 1
	WVS: variety of wheat sown	not recommended = 0 recommended = 1
	SSM: seed planting method	broadcast = 0 drill sowing = 1
	FAM: fertilizer application method	broadcast application = 0 side dressing = 1
	AFS: applying FYM into the soil	no = 0 yes = 1
	MOH: mode of harvesting	manual harvesting = 0 harvesting through reaper or harvester= 1

RESULTS AND DISCUSSION

Descriptive analysis summarizes the information on situation regarding qualitative attributes of explanatory variables by presenting the percent values. Frequency, percentage, mean values and standard deviation were calculated. Econometric analysis, by applying multiple linear regression through ordinary least square method, investigates the relationship between of wheat yield and qualitative attributes of the explanatory variables included in the model.

Table 2. Descriptive summary of qualitative attributes of determinants of wheat yield.

Type of Variables	Names of Variables	Qualitative Attributes of Variables
Socioeconomic Variables	farmer's literacy	illiterate = 56.7% literate = 43.3%
	land ownership status	having no land ownership = 23.3% having land ownership = 76.7%
Agronomic Variables	fertility status of soil	poor or average = 65% good = 35%
	source of irrigation	tube well only = 9.2% canal and tube well = 90.8%
	laser levelling status of land	conventionally levelled = 48.3% laser levelled = 51.7%
	variety of wheat sown	not recommended = 15% recommended = 85%
	seed planting method	through broadcast = 32.0% through drill = 68.0%
	method of applying fertilizer	broadcast application = 94.9% side dressing = 5.1%
	applying FYM into the soil	no = 85.8% yes = 14.2%
	mode of harvesting	manual harvesting = 68.3% harvesting through reaper or harvester= 31.7%

Wheat growers' socioeconomic profile and the adopted agronomic practices

Table 2 indicates that, the socioeconomic variables have qualitative answers on the farmer's education and on the status of land ownership. According to the descriptive statistics, majority (57%) of the wheat producers in the study area were illiterate. More than one fifth (23%) of the farmers did not have their own agricultural land and cultivated wheat as tenants. Each agronomic variable signifies the characteristics of a particular agronomic activity linked to the production of wheat crops and has a binary response. The information recorded in this set of variables characterizes two attributes of each variable or agronomic activity chosen by the farmer for wheat crop production. A large number (65%) of respondents reported that the fertility status of their land was not good (medium or poor). For irrigation purposes, about 9% of farmers had no canal water available and were depended on the tube well water as a source of Wheat yield has been modelled as an outcome of socioeconomic and agronomic variables. All the irrigation for wheat crop. Results showed that in the area studied, 48.3% of total farmers were not levelling farm land with laser levelling and 15% of wheat producers were not planting the recommended variety. Respectively, 68% and 95% of farmers used the broadcast method for sowing wheat seeds and for applying chemical fertilizers. Only 14% of wheat producers practiced the application of manure in their cultivated lands to maintain soil health. Over 68% of wheat farmers manually harvested the wheat crop.

Socioeconomic and agronomic interpretation of wheat yield in cotton-wheat Punjab

The OLS estimation found that two socioeconomic attributes (farmers literacy and land ownership status) and five agronomic variables significantly influenced the quantitative response of wheat yield.

Table 3. Estimated regression equation coefficients

Dependent Variable: Yield Wheat			
Explanatory Variables		Coefficients (St. Error)	t-stats
	(Constant)	1.678***	13.413
Socioeconomic	Farmer's literacy	0.142*** (0.795)	2.167

Variables	Farmer's Land-ownership status	-0.159** (0.875)	-2.581
Agronomic Variables	Fertility status of soil	0.109* (0.810)	1.702
	Source of irrigation	0.312*** (1.431)	4.536
	Laser leveling status of land	0.101 (0.737)	1.648
	Variety of wheat sown	0.023 (1.053)	0.361
	Seed planting method	0.353*** (0.928)	4.878
	Method of applying Fertilizer	-0.065 (1.745)	-1.023
	Applying FYM into the soil	0.116* (1.082)	1.854
	Mode of harvesting	0.218*** (0.783)	3.590
Model Diagnostics			
$R^{2,}$ 0.624	Adjusted R^2, 0.5970;	S.E of regression, 3.865	

Note: *** indicates significance level 1%, ** indicates significance level 5%, and * indicated significance level 1%

Our estimated regression equation could be written as:

$$WY = 1.678 + 0.142LIT^{***} - 0.159LOS^{**} + 0.109SFS^{*} + 0.312SOI^{***} + 0.101LLS + 0.023WVS + 0.353SSM^{***} - 0.065FAM + 0.116AFS^{*} + 0.218MOH^{***} + \epsilon_T$$

Wheat yield responses to socioeconomic characteristics of growers

The two contextual variables were found to statistically affect crop yield. A farmer's literacy was positively associated with crop yield and the variable was significant at a significance level of 5%. Through a multiple way, better educational status of the growers could be advantageous for them over the illiterate farmers. Theoretically our findings are in line with some studies (Alam, 2001; Dixon *et al.*, 2008; Memon, 2017). Likewise, in comparison with landless peasants (tenants), owner-operators obtained fewer yields from the harvest. The relationship was significant at a significance level of 5%.

Agronomic interpretation of wheat yield

Cropland with good soil fertility was positively associated with crop yield and was found to be significant at the 10% level of significance. Similar outcomes are evident from literature as well (Alam, 2001; Memon, 2017). The irrigation which is the part of this study, the quality of the standard of underground water which is pumped through pipes is less than the water from the canals. So, according to our results the farmers with access to canal water for irrigation had better crop yield as compared to the farmers who were totally dependent on underground water for irrigation. Same response of wheat crop yield is endorsed by Tahir *et al.* (2003). The farmers have to bear the cost of energy for pumping the water through tube wells for irrigation of lands. In the context of Pakistan, shortage of electricity, high fuel cost, poor quality of underground water, and finally the lower yield outcomes are more than suffice to ruin a small or landless farmer in financial terms.

Based on the theoretical evidences provided by the literature (Das *et al.*, 2018; Jat *et al.*, 2003; Jat *et al.*, 2006; Hoque and Hannan, 2015; Naresh *et al.*, 2014), it was hypothesized that the levelled agricultural lands with lasers were positively related with crop yields. The direction of the relationship was similar to as hypothesized, but the variable was not considered statistically significant. Likewise, based on the theoretical support (Alam, 2001; Memon, 2017), it was also hypothesized that a farmer cultivating a recommended variety of wheat would obtain a higher crop. In our findings, the direction of the relationship was similar to the hypothesized one, but the variable was not considered statistically significant.

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Seed sowing through drill is an up-to-date technique used to plant wheat. The results of the regression show that a farmer who sows the seed through drill (instead of planting by broadcast) has a greater yield. Same research outcomes have been recorded by Limochi *et al.* (2014) and Chauhdary *et al.* (2016). The application of fertilizers through fertigation or spraying has been identified for healthier nutrient absorption in crops, and this method is considered more effective than the conventional broadcast method, but in the current study this coefficient was found to be negatively and statistically insignificantly associated with wheat crop yield. The use of organic fertilizer in complement with synthetic fertilizer is acknowledged as a key factor to enhance the soil fertility for the sustainable use of agriculture lands (Alam *et al.*, 2003; Ali *et al.*, 2014). In our results, it was found that the application of farm yard manure at some stage in wheat production had statistically significant effects on increasing crop yield. Instead of manual harvesting, it was found that harvesting through the reaper or through harvester was associated with higher wheat yields, the relationship was statistically significant at the 1% significance level. The same recommendations have already been endorsed by a few studies (Alam, 2001; Sattar *et al.*, 2015).

Model diagnostics

R square is a measure used for the goodness of fit index of the model (Gujarati, 2004). So, it explains the responsiveness or change in the explained variable Y due to exploratory variables. According to model diagnostics of regression, R-square value is almost 0.62, which shows that 62 percent exploratory variables explain the explanatory variable.

The total sum of squares equals the summation of the estimated sum of the squares and the amount of the residual sum of squares (Gujarati, 2004). Thai is, the total variation of the values of Y observed from its average value can be divided into two parts, one attributable to the regression line and the other to random forces, since all the real Y observations do not appear on the processed line.

Table 4. Analysis of variance.

Sum of Squares (SS)	SS Values	df	Mean Square	F value	Sig.
Residual sum of squares RSS	1628.44	109	14.94		
Estimated sum of the squares (ESS)	2708.55	10	270.86	18.13***	0.000
Total sum of squares (TSS)	4336.99	119			

*** indicates significance level 1%, ** indicates significance level 5%, and * indicated significance level 1%

R-square value and F-statistics value are directly linked with each other. The higher value of R-square with higher value of F- statistics indicates that the estimated regression results are statistically significant. The null hypothesis indicates that there is no impact on the regressors, so the significant F-statistics indicates that we reject the null hypothesis, which indicates that there is statistically significant effect over the regressors, regardless with the small value of R-square. According to Table 4 indicates that the F values are statistically significant, so the explanatory factors have a significant impact on agricultural yield production. Thus, overall model is good fit.

CONCLUSION AND RECOMMENDATIONS

The study following an input-output model and with its specific focus on the qualitative attributes of farmland, agricultural labor, and farm capital engaged in wheat production, the current study has modelled wheat yield as an outcome of the qualitative attributes of some socioeconomic and agronomic variables. Punjab shares more than 70 percent of the country's total area cultivated under wheat crop. While making a comparison among top 10 wheat producing districts of Punjab, district Bahawalnagar is ranked first regarding its share in total wheat production. Better educational status of the growers was found associated with higher wheat yield, however majority of the wheat producers in the study area were illiterate. A large number of growers reported medium or poor fertility status of their land, while cropland with good soil fertility was found to be positively associated with crop yield. Similarly, a considerable proportion of the growers had not laser-levelled farmlands, whereas the agricultural lands levelled with lasers were positively related with wheat yields. A significant number of growers were opting broadcast method for seed-sowing but seed sown through drill had enhanced yield outcomes. It was found that the application of farm yard manure at some stage in wheat production had statistically significant effects on increasing crop yield, while only a very small number of wheat producers were applying farm yard manure during wheat cultivation. Majority of growers was harvesting the wheat crop manually, whereas harvesting through the reaper or through harvester was associated with higher yield outcomes. The study concludes that in the context of wheat-cotton Punjab, qualitative attributes of the wheat growers and that of agronomic practices matter in determining wheat yield. The study suggests the need for farmer's education & trainings and the need for improvement of canal irrigation infrastructure. Agricultural extension education and agricultural credit-provision related programs are required to be more specifically focusing on landless farmers. Awareness raising programs are also needed to educate the farmers regarding conservation of natural resources (especially agricultural lands) through application of organic fertilizers. Farmer's education and trainings would also be required to convince them to adopt modern ways to apply farm inputs as well as to harvest farm output, respectively to enhance input efficiencies and to avoid output losses.

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