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Determination of Optimal Input Usage into the Wheat Production for *Kareze* Irrigation in the Balochistan, Pakistan

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Abstract: This study examines the wheat profitability and factors affecting its production under the *Kareze* irrigation system in Qilla Abdullah, Balochistan, Pakistan, during the year 2002-2003. The profitability of wheat was estimated using enterprise budget technique whilst log-linear Cobb-Douglas production function was developed to analyze the factors affecting wheat production. The result indicates that wheat is a profitable crop under *Kareze* irrigation system. Water availability through relatively inexpensive *Kareze* water and high use of inputs are the major contributors to high net returns and benefit cost ratio. The empirical results suggest that Diammonium Phosphate (DAP) Farm Yard Manure (FYM) and size of the plot are the key inputs affecting wheat production. The comparison of farm-level inputs use with the recommended inputs use by the national and international agricultural organizations show that farmers are roughly applying the recommended inputs level, which is also one of the main reasons for obtaining high wheat yield. Based on the empirical findings, it is recommended that farmers should increase the quantity of diammonium phosphate and farm yard manure to obtain maximum yield.

Key words: Wheat, Cob-Douglas production function, optimal input use, *Kareze* irrigation, Pakistan

INTRODUCTION

Pakistan is basically an agriculture country. Agriculture contributes over 25% of the national income, provides employment to 44% of the total labor force and three fourth of the country's exports. Crop production accounts for approximately 70% of the value of agricultural product in Pakistan (Economic Survey, 2005). It is vitally important both in providing domestic food and fiber supplies and serving as a major source of foreign exchange earnings through export of both raw materials and processed crop commodities.

There are two principal crop seasons in Pakistan, namely the *Kharif*, the sowing season which begins in April-June and harvesting during October-December and the *Rabi*, which begins in October-December and ends in April-May (Subhan *et al*., 1999; Economic Survey of Pakistan, 2005).

Wheat is staple foods crop grown in *Rabi* season and dominating all crops in area and production. It contributes 12.1% to the value added in agriculture and 2.9% to Gross Domestic Product (GDP). Wheat accounts for 37.1% of the crop area, 65% of the food grain acreage and 70% of the production (Agricultural Statistics of Pakistan, 2005). The Indus Plains with their favorable topography, rich soils and good agricultural facilities provides an ideal land for wheat cultivation.

Wheat is grown as a *Rabi* crop in all four provinces of Pakistan. During the year 2004-05, wheat was cultivated on an area of 8.36 million hectare with an estimated production of 21.62 million tons. The major wheat producing areas are Punjab (76%), followed by Sindh (11%), NWFP (8%) and Balochistan (5%) (Agricultural Statistics of Pakistan, 2005).

Balochistan is the largest province of Pakistan comprising 44% of the total geographical area. Wheat is not only chief a source of staple food for people but also provide essential livelihood opportunities (Shah *et al*., 2002). During 2004-05, the total area under wheat cultivation was about 343.1 thousand hectare, out of which 281 thousand ha was under high yielding wheat varieties such as Inqilab-91, Zardana and Zarghoon and 62 thousand hectare were under traditional wheat verities. Total production during the same period was about 636 thousand tons with an average yield of 1,858 kg ha^{-1} (Agricultural Statistics of Pakistan, 2005).

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Balochistan has been endowed with a variety of environmental conditions, which favors growing of a large number of crops. The province produces 60% of its wheat requirement, while the deficit is met through imports from other provinces. The major wheat producing areas in the province are Nasirabad, Jaffarabad, Bolan, Loralai, Khuzdar, Kharan, Pishin and Qilla Abduallah districts. Among them, Nasirabad and Jaffarabad rely on large canal water diverted from the Indus River, Bolan, Loralai, Khuzdar, Pishin and Qilla Abduallah utilise tubewell and *Karezes* (underground channels) water and Kharan and Kachhi depend on rain and tubewell water.

Agriculture production involves the use of various interlinked inputs such as are conventional, physical, biological and environmental inputs. To achieve the goal of higher agricultural production, optimal use of inputs is often recommended. Input can be conventional such as land, labor, capital and management, physical such as fertilizer, pesticide, biological such as seed and other genetic recourses, irrigation and environmental such as soil, rainfall and temperature. Noor (1988) and Talug *et al.* (1998) reported that maximum yield depends on several factors but organic and inorganic fertilizers play a vital role to ensure maximum yield coupled with improved varieties on different soils.

Various national agricultural research departments such as Pakistan Agricultural Research Council (PARC) and provincial Agricultural Research Institutes (ARIs) and international organizations such as Food and Agricultural Organization (FAO), based on their field trails, often recommend optimal input uses. However, their recommendations have been seldom evaluated with actual farmer's practices. In addition, the input uses have rarely tested empirically at farm-level.

Currently, it is observed that there is a huge gap between the farmer's level and research stations' level wheat production. This is due to inefficient input use, lack of extension services, lack of improved technology and lack of agriculture education (CIMMYT, 2006; Shah *et al.*, 2002). Therefore, the aim of this study is to determine the optimal input usage by evaluating the current resource use pattern at farm-level and at the research station level. Particularly, the objectives of the study are (i) to develop wheat crop production budgets and determine profitability of wheat production; (ii) to determine the factor affecting wheat production by developing production function and (iii) to identify and compare gaps between the current resource use pattern with recommended inputs using wheat budget and production function.

MATERIALS AND METHODS

Study area: The study was conducted at Messazai and Pir Alizai villages of Qilla Abdullah District of Balochistan Province, Pakistan (Fig. 1). The population of Qilla Abdullah district was estimated to be over 400,000 in 2005. The area is bounded by the lower edge of Sulaiman range (an extension of the Himalayas) extending over a major portion of the north-west part of the area. Capital of Balochistan, Quetta lies on east side of the study area. Northern part joins similar arid areas of Pishin. This area has an arid with sub-tropical continental climate. The mean annual rainfall ranges from 300 to 350 mm. The rainfall pattern is erratic and uncertain. About 60% of the rainfall occurs in Monsoon season (July and August) usually in the form of intense showers causing floods. July is the hottest month with a mean maximum temperature of 30°C. January is the coldest month with a mean minimum temperature of 5°C. The source of water is three *Kareze* and a seasonal watercourse with planned flows of almost 200 to 700 m^3 h^{-1} (2 to 7 cusecs). Public as well as private tube wells are also installed in the area.

Sampling procedure and sample size: Two sets of questionnaires were developed - one for the village level (group survey) and the second for the households level. A multistage sampling methodology was used. In the first stage, 2 villages were selected at purpose. The village selected purposively presented fairly good representation of different topographies (e.g., hilly, intermediate, flat) and farming characteristics of the area. In the second stage, 37 farms were randomly selected to adequately represent the villages. The data were collected from each of the farmers about the number of family members engaged in farming operations, the number of permanent hired labors, the number of plots and their size and extension officer's visits. For each crop-plot, information was collected about the inputs of including human labor, variety, fertilizer, harvesting, threshing, yield and prices.

In addition to the primary data collected from sample farmers, this study also utilize historical data on crop area, production and prices from various provincial and national statistics such as economic survey of Pakistan, agricultural statistics of Pakistan and Balochistan.

Models

Profitability of wheat: Net economic returns were calculated to estimate the economic efficiency of wheat production. The net economic returns were calculated as gross returns minus the costs of all

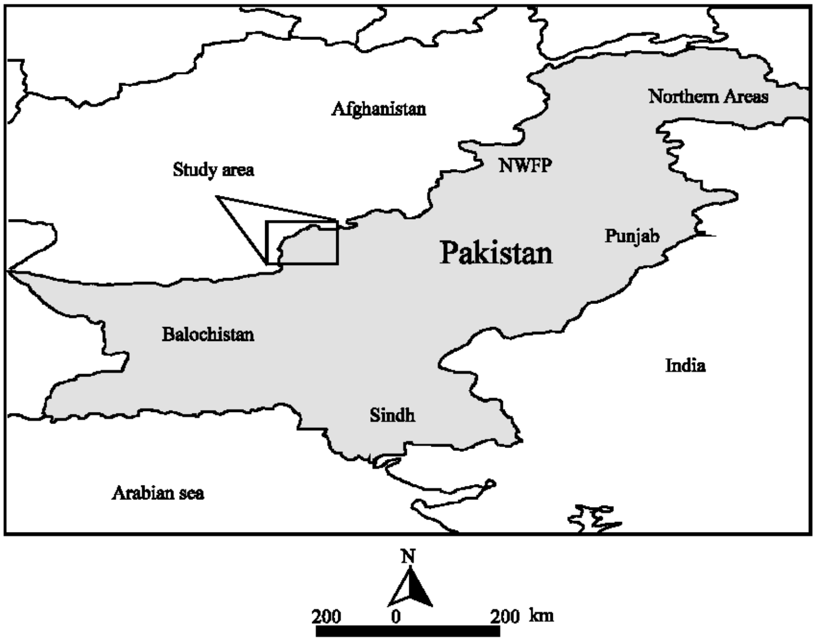

Fig. 1: Location of Study area, Qilla Abdullah, Balochistan, Pakistan

variable inputs, which include the cost of irrigation, seed, fertilizer, chemical and labor (FAO, 1997). The average household size in the study area was 8.4 members. Considering this fact, combined with unemployment, we assume that household labor may not have opportunity costs. Therefore, the imputed costs of family labor were not included while calculating the net returns from wheat.

Price estimates and model assumption: Prices highly influence investment calculation. Most often market prices are directly chosen after harvest, but they tends to be either too high or too low and thus do not reflect the averaged price received by the farmers. In case of more periodic analysis, the best bases for calculation consist of empirical prices and yield information to allow comparison. Since this data often does not exist, average farm gate prices are reasonable substitute. In the analysis, all stochastic variables such as yield and price represented in the model were used by their mean values. The distribution of prices and yields was assumed to be stationary. The price estimates and assumptions for various input and output are as follows:

- Regarding charges on human labor force, it was observed that three types were used by the farmers for all the agricultural operations of various crops. These were family, permanently and casually hired labor. The prevailing market rate for 8 h of work in normal times was about Rs. 100 in the villages.
- The hiring charges of tractors (average size of 37 kW) varied from operation to operation. In the case of ploughing, the charges were Rs. 150 h^{-1} and for threshing the charges were about Rs. 250 h^{-1}.
- A common seed rate of wheat was 125 kg ha^{-1} in the district. Depending on the seed type and variety, the price of wheat seed varied from Rs. 10.50 to 12.00 kg^{-1} with an average value of Rs. 11.00 kg^{-1}. Therefore, the price of commonly observed wheat variety (*Zarghoon*) was used in the analysis.
- The costs of fertilizers applied were almost similar through out the district. Two types of chemical fertilizers were commonly used at the farms; nitrogenous fertilizer (Urea) and Diammonium Phosphate (DAP). The market price of a 50 kg bag of Urea and DAP was Rs. 440 and Rs. 930, respectively.
- Gross value of output includes the value of wheat and wheat straw. Value of the wheat crop was computed using an average market price (farm gate price) of Rs. 7,000 ton^{-1} which farmers received during 2003-2004. The quantity of straw was calculated from the grain yield. Each ton of wheat grain produces 1.25 tons of straw. An average price Rs. $1,250^{-1}$ of straw was used in the analysis.

Empirical model: The Cobb-Douglas models have been extensively used extensively to examine the relationship between inputs and output (Ozsabuncuoglu, 1998; Singh *et al.*, 1998; Oweis and Hachum, 2003). To analyze the relationship between inputs and yield several structural form of Cobb-Douglas production function were tried. Among all, linear-logarithmic model showed better estimates in terms of statistical significance and expected signs of parameters. The Cobb-Douglas model is generally expressed as:

$$Y = \int(x)\exp(u) \quad (1)$$

The model can further be expressed in the following terms.

$$\ln Y_i = \alpha + \sum_{j=1}^{n} \beta_j \ln(X_{ij}) + e_i \quad i = 1,2,\ldots,n \quad (2)$$

where Y_i denote the yield level of the ith farmer, X_{ij} is the vector of inputs used in the production process, α is the constant term, α_j represents the coefficients of inputs which are estimated from the model and e_i is the error term. Eq. (2) is further expanded in accordance with the assumption that the yield is the function of inputs including human labors hours (Lbr), tractor hours (Tr), chemical fertilizers (Fert), Farm Yard Manure (FYM), seed and irrigation (Irri). Equation 2 can be written in the following empirical form;

$$\begin{aligned}\ln Y_i &= \alpha + \beta_1 \ln(\text{Lbr}) + \beta_2 \ln(\text{Tr}) + \beta_3 \ln(\text{Fert}) \\ &+ \beta_4 \ln(\text{FYM}) + \beta_5 \ln(\text{Seed}) + \beta_6 \ln(\text{Irri}) + e_i\end{aligned} \quad (3)$$

According to Green (1997), the output elasticity of the ith factor with respect to X_i can be calculated as:

$$\alpha_i = \frac{\partial \ln Y}{\partial \ln X_i} \quad (4)$$

The data were processed in LIMDEP 7 computer software.

RESULTS AND DISCUSSION

Physical budget and profitability of wheat: The physical wheat budget and profitability was determined on hectare basis. Profitability is an indicator for a farmer to decide whether to grow a certain crop or not and which of the crops provides better economic returns. The profitability of water was calculated based on partial enterprise budgeting. The physical crop budget and profitability of wheat production with *Kareze* irrigation are given in Table 1. The inputs uses were found to be high-126 kg ha^{-1} of seed, 153 kg ha^{-1} of Urea, 63 kg ha^{-1} of DAP and 270 h ha^{-1} of man power-as compare to Balochistan average-100 kg ha^{-1} of seed, 105 kg of Urea ha^{-1}, 55 kg of DAP ha^{-1} (Agricultural Statistics of Balochistan, 2005). However, the high use of inputs were justified with a significantly higher yield (3,163 kg ha^{-1}) as compare to average yield in Pakistan (2,586 kg ha^{-1}) and Balochistan (1,858 kg ha^{-1}) (Table 2). This was due to the fact that the study area is famous for agricultural activities, *Kareze* irrigation and high use of input. The inputs uses were found consist with the study conducted at the similar area by Jagirani *et al.* (2003) under the project the project Integration of Agriculture Research and Extension.

The major cost on wheat production was incurred on fertilizer (Rs. 2,041 ha^{-1}), which was about 30% of the total cost. The machinery such as tractor for ploughing and threshing cost Rs. 1,665 ha^{-1}, which was almost 25% of the total costs. Because of the fact farmers used hybrid seeds, which costs more than the traditional seeds, the seed cost was about Rs. 1,391 ha^{-1} or 21%.

Profitability showed that wheat is profitable crop to grow in the study area. The net return from wheat production was about Rs. 18,724 ha^{-1}. However, the returns were calculated without the imputed costs of family labors because of the fact that family labors have no opportunity costs as they are in abundant. One of the reasons for high net returns was relatively inexpensive *Kareze* water, farmers paid very small amount for water to irrigation. The benefit cost-ratio of wheat production was 3.77 that also indicate the wheat is highly profitable crop under the *Kareze* irrigation (Table 1).

Table 1: Physical crop budget and profitability of wheat under *Kareze* irrigation, Balochistan (ha^{-1})

Variables	Physical budget	Cost and benefits of inputs and outputs (Rs.)	Cost and benefits of inputs and outputs (%)
Inputs			
Fertilizer (kg)	417.06	2,041.32	30.21
Urea (kg)	153.47	1,074.31	15.90
DAP (kg)	63.95	767.37	11.36
FYM (kg)	199.64	199.64	2.95
Machinery (h)	9.52	1,665.50	24.65
Human (h)	269.41	779.53	11.54
Diesel (l)	38.07	574.77	8.51
Seed (kg)	126.52	1,391.74	20.59
Irrigation (man-hours)	26.07	304.97	4.51
Total inputs		6,757.83	100.00
Outputs			
Yield (Grain) (kg ha^{-1})	3,136.22	23,521.66	92.31
(Straw) (kg ha^{-1})	3,920.28	1,960.14	7.69
Total output		25,481.80	100.00
Gross return (Rs. ha^{-1})		25,481.80	
Net return (Rs. ha^{-1})		18,723.97	
Benefit Cost Ratio (BCR)		3.77	

Empirical result: Cob-Douglas production function was used to determine the relationships of inputs with outputs. The results of the regression analysis are presented in Table 3. According to the results, F value was found significant ($p< 0.01$), which indicates that model was overall significant. The values of R^2 adjusted R^2 was 0.99 and 0.98, respectively. The value of adjusted R^2 such as 0.98 imply that 98% of the variation in the yield was explained by the variables included in the model. The coefficients estimated in the model were in accordance with the *a priori* expected signs.

The elasticity is particularly useful for determining the relationship between input and yield. Since the logarithmic form of Cobb-Douglas production was used coefficient represents elasticity. The coefficients of DAP, FYM and size of the plots were significant at $p<0.001$, which implies that a small change in DAP, FYM and plot size will results in a significant change on yield. On the other hand, the coefficients of tractor, seed, urea, labor and numbers of irrigation were found insignificant (Table 3).

The elasticity of DAP was 0.02, implying that given 10% increase in DAP use will result in 0.2% increase in wheat yield. This was because farmers in the study area were applying sub-optimal doses of DAP. This also suggests that there is room to increase wheat yield by applying recommended doses of DAP. Similarly, the elasticity of FYM was 0.012 indicated that 10% change in (FYM) will result 0.12% increase in wheat yield. Rest of the variables can be interpreted similarly.

Table 2: Province wise wheat area, production and yield, 2004-2005

Province	Area (hectares)	Production (tons)	Yield (kg ha^{-1})
Punjab	6,378.9	17,375.0	2,724
Sindh	887.4	2,508.6	2,827
NWFP	748.6	1,091.1	1,458
Balochistan	343.1	637.6	1,858
Pakistan	8,358.0	2,1612.3	2,586

Source: Economic Survey, 2005-06, Government of Pakistan

Table 3: Econometric estimation factors affecting wheat yield under *Kareze* irrigation, Balochistan

Variables	Coefficients	Standard error	p-value
Intercept	2.373***	0.231	0.000
Tractor	0.091**	0.043	0.046
Seed	0.103	0.151	0.502
Urea	0.285	0.067	0.957
(DAP)	0.02***	0.004	0.00
Labors	0.041	0.06	0.50
(FYM)	0.012***	0.003	0.00
Irrigation	0.013	0.127	0.92
Plotarea	0.476***	0.136	0.002
F-value	420.45***		
R^2	0.99		
Adjusted R^2	0.98		
No. of observations	37		

***, ** and * indicate the significance at 1, 5 and 10% probability levels, respectively

Comparison of current and recommended input use: Table 4 presents comparison between the current inputs use at farm-level with the recommended input use by the National Coordinated Wheat Program under Pakistan Agricultural Research Council (PARC, 2004) in collaboration with Agricultural Research Institute (ARI), Balochistan and optimal fertilizer use by crop in Pakistan by FAO. The comparison showed that the farmers in the study area were almost using optimal level of input use. Farmers were using approximately same quantity of seed, urea and applying optimal labor for wheat production. However, in some cases, the application of urea was more than the recommended use. The labor use at farm-level was also showed high but not significant than the recommended labor use. It maybe some of the labor, especially family labors, under utilized.

On the other hand, farmers in the study area applied DAP and FYM well below the recommended level. This could be one of the reasons for lower yield as compared to optimal yield obtained after applying recommended input level. It is obvious that if the farmers will apply inputs optimally then they can obtain yield up to 3,600 kg ha^{-1}. The comparison of current and recommended input use was consistent with the econometric model. The coefficients such as urea, labor and seed did not show any signification impact on yield, whilst the coefficient of DAP and FYM indicated considerable potential for increasing wheat yield (Table 4).

Table 4: Comparison of current and recommended input use under *Kareze* irrigation in Balochistan (ha^{-1})

Variables	Current	Recommended	Mean Difference*
Inputs			
Fertilizer (kg)			
Urea (kg)	153.5	125	28.5^{NS}
(DAP) (kg)	64.0	125	-61.1^{S}
(FYM) (kg)	199.6	1250	-1050.4^{S}
Ploughting (h)	2.5	3	-0.5^{NS}
Threshing	1.8	NA	NA
Human (h)	269.4	250	19.4^{NS}
Diesel (L)	38.1	NA	NA
Seed (kg)	126.5	123.5	3.0^{NS}
Irrigation	4	5	-1.0^{NS}
Outputs			
Yield (grain) (kg ha^{-1})	3,136.2	3,600.0	-463.8^{NS}
Yield (Straw) (kg ha^{-1})	3,920.2	5,400.0	-1479.7^{NS}

*10% level of significant; S = Significant and NS = Non-significant NA = Not applicable

CONCLUSION AND RECOMMENDATION

Agricultural practices determine the level of food production. Agriculture production involves the use of various interlinked inputs to achieve the desired level of outputs. To achieve the goal of higher agricultural production, optimal use of inputs is often recommended. However, there are massive gaps between farm-level input uses and the recommended input uses.

The study was conducted in the Qilla Abdullah District of Balochistan Province, which is one of the major agricultural areas in the Province. The major aim of the study was to pin point the optimal input gaps between the farm level input use and research station level and determine the factor affecting the wheat yield under *Kareze* irrigation.

The study pointed out that wheat was profitable crop. The high net returns and benefit cost ratio of wheat were mainly due to relatively inexpensive *Kareze* water and high use of inputs such as urea and labor. The empirical result showed that the coefficients of DAP, FYM and size of the plots were significant while the coefficients of tractor, seed, urea, labor and numbers of irrigation were insignificant. The comparison of current farm-level inputs use with recommended inputs by various national and international departments revealed that farmers in the study area were applying almost the recommended level of input use. The empirical results from Cob-Douglas model quantified and validated the optimal and sub-optimal input use under *Kareze* irrigation.

Based on the findings, it is recommended that the quantity of DAP and FYM should be increased according to the recommendation of the national and international agricultural departments to obtain maximum yield. This must be complimented with the extension services so that the farmers can get maximum benefits from the latest research outcomes technologies and inventions.

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