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Estimating wheat productivity function under capricious irrigation sources: an evidence from the upland Balochistan

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Abstract

The aim of this study was to estimate the determinants of wheat productivity on varying irrigation sources in the upland Balochistan. Wheat growers including tubewell owners, water buyers and rain-fed farmers were selected from the five districts of upland Balochistan. Wheat crop was chosen for its wide coverage and cultivation across the study area. The results of the wheat productivity function analysis showed that among other crop inputs fertilizer and organic farm yard manure (FYM) have significant positive effect on wheat yield. While the number of irrigations (IRRI) has positive and seed rate has negative relationship with wheat yield. The source of irrigation specific dummies shows that yield of tubewell owners was greater than that of water purchaser and rain-fed grower. The comparison of wheat productivity of tubewell owners, water buyers and water non-buyers shows the economic effect of tubewell irrigation on crop productivity by providing a reliable access to irrigation water. The rain-fed farmers got the lowest yield for not having assured irrigation. One of the key findings of this study is that overall productivity can be increased by a reliable water supply through tubewells, the water in excess of own needs can be sold to fellow farmers to ensure the full utilization of tubewell capacity. The results also show the importance of tubewell irrigation in enhancing productivity leading to self-sufficiency in food production for increasing population.

Key words: Wheat, productivity function, tubewell, irrigation, water buyer, upland Balochistan

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Introduction

Globally fresh water withdrawn for agriculture is 67%, domestic and industrial use 20%, power 10%, while 3% is evaporation losses from reservoirs (Parliamentary Office of Science and Technology (POST), 2011). Intensive use of groundwater is common in many parts of the world, particularly in arid and semi-arid areas. Groundwater is generally a reliable and good quality water source, and with modern technology for drilling, electrification and pumping, it is widely accessible in many parts of the world today (Villholth and Giordano, 2007). Groundwater is an important factor for reducing poverty and malnutrition, and improving sanitary conditions; it has helped farmers to overcome the poverty thresholds in many regions (Custodio et al., 2004).

Millions of farmers and consumers have benefited from the growth of groundwater use all around the world. It is evident from the fact that during the period 1975 through to 1995, the rapid growth in groundwater irrigation in South Asia and the North China plains has been the main driver of the groundwater boom in these regions which resulted in the ` growth and creation of millions of rural livelihoods (Mukherji, 2004; Qureshi et al., 2008; Shah et al., 2003; Shah et al., 2006). It has been a major element of programmes aimed to improve livelihoods for the poor in the developing countries of Asia and Africa (Shah et al., 2006). The major stimulating factor for groundwater development has been the groundwater-related policies adopted by the governments in many of the countries of South Asia and China (Mukherji and Shah, 2005; Qureshi et al., 2008; Shah et al., 2003).

The groundwater brought about an agrarian boom in South Asia during the past two decades. This creates a complex and difficult challenge as more than 50-60% of populations are now directly or indirectly dependent upon groundwater irrigation (Shah et al., 2003). Due to the more reliable water supply through tubewells, yields in areas irrigated by groundwater are often substantially higher than yields in areas irrigated by surface sources (Meinzen-Dick, 1996; Shah, 1993;). In India, groundwater-irrigated areas account for about half of the total irrigated area and some 70-80% of the country's total agriculture production may be groundwater dependent (Dains and Pawar, 1987). In Pakistan, the groundwater constitutes 40% of the total agriculture water supplies in the Punjab province, which produces around 90% of the country's food (Qureshi and Barrett-Lennard, 1998).

The irrigated agriculture sector in Pakistan is facing the challenge to cope with low crop yields, increasing gap in the supply and demand of agriculture products, decreasing trend in agriculture productivity and agricultural production. Tubewells are an important source of irrigation in Balochistan and irrigated more than half of total irrigated area. Tubewell irrigation increases the reliability of water for crop growing. The reliability refers to a situation when a farmer knows with certainty that he will be able to get tubewell water at a given time. The reliability of the irrigation source is important in the sense that the productivity of irrigated agriculture is mainly determined by a timely and reliable water source (Meinzen-Dick, 1996). Most of the literature related to the effect of irrigation water available through tubewells pertains to a few South Asia countries and China. Only a few studies were found underlining the impact of tubewell irrigation on crop choices, agricultural productivity and incomes. Tubewell irrigation is said to have increased the irrigation reliability (Meinzen-Dick, 1996). Water obtained through owned tubewells or purchased increases the irrigation reliability and hence affects the crop choices and crop productivity of both tubewell owners and water buyers (Meinzen-Dick, 1998). A reliable water supply ensures the use of modern inputs such as organic fertilisers, pesticides, improved seeds, etc. that affect crop productivity (Meinzen-Dick, 1998& Shah, 1993).

Groundwater markets increase the total water available for crop growth, hence affecting crop choices and crop productivity, and causing farmers to shift from low value to high value crops (Bahadur, 2004; Bhandari and Pandey, 2006; Shah, 1993). Meeting the irrigation water requirements of crops, either through their own tubewells or obtained purchased from fellow farmers, is most important to achieve a better crop yield and profits. Besides irrigation water, farm mechanisation, the use of other important inputs such as pesticides, seed, and fertilisers, and, more importantly, favourable weather conditions are the main determinants of the farm income (Bahadur, 2004).

The importance of irrigated agriculture to the Pakistan economy is explained by the fact that irrigated land supplies more than 90% of agricultural production and contribution of agriculture to GDP is 21 %, and employs around 45% labour force (Government of Pakistan, 2014). Pakistan's water resources country have been under tremendous pressure similar to many other developing countries of the region such as China, India, and Iran due to factors such as increasing population, improved living standards, urbanization, and climate change. As a result, the per capita availability of water is on a decline in Pakistan. Moreover, the irrigated agriculture in Pakistan is being confronted by the problems of unequal distribution of water, water logging and increasing soil salinity that are causing low crop yields and social disparity as well (Zaidi, 2004). Especially in the areas under canal irrigation system; the distribution of water is characterized by inequity at different levels i.e., along the main canals-their distributaries and within water courses (Latif & Ahmad 2007). The water shareholders at the head of the distributaries do get sufficient water concomitant with their share but those at the middle and the tail end often don't get enough water equivalent to their allocated share. The dilemma facing the farmers of tail end is not only the insufficient water short of their share from canal system, but the quality of groundwater at the tail ends of the irrigation system is also poor and mostly saline that not only reduces their crop yields but also causing land degradation (Latif & Ahmad, 2007).

Some studies undertaken in the past focused mostly on soil and agronomic factors and less on water related factors at farm and at systems level (Hussain et al., 2004;Mushtaq et al., 2007). This study thoroughly analyzes a fairly wide-ranging set of agronomic and water related factors such as the quantity and quality of different inputs and their influence on wheat yields under tubewell irrigation (either own tubewell or purchased water) and wheat yields obtained under rain-fed cropping in Balochistan.

Methods

This section presents a general description of the study area and its agriculture and the theoretical aspects of the research methods employed to undertake the research. It also presents the theoretical frameworks and empirical models used. The empirical model for measurement of wheat productivity is presented.

The study area

Balochistan is the south western province of Pakistan that is located between latitudes 25^0 and 32^0 N, and longitudes 61^0 and 71^0 E. The geographical area of Balochistan is around 347,190 square kilometres. The provincial plateau is mostly comprised of hilly terrain. Balochistan has an annual rainfall of less than 250 mm on average. The province can be classified as a dry/arid region, and thus the reliance on rainfall for crop growing is low, which intensifies the search for a more reliable water source to secure irrigation to ensure high crop yields for the Balochistan farmers.

The study area of Upland Balochistan can be classified as arid in terms of rainfall, receiving an average rainfall of 200 mm to 250 mm annually, which emphasises the need for irrigation water in this area for high value crops. The upland comprises the Ziarat, Kalat, Quetta, Pishin, Killa Abdullah, Mastung, Zhob and Loralai districts of Balochistan.

Balochistan is characterised by having a diversified climate which ranges from semi-arid to hyper-arid. Temperature regimes vary widely, from cool temperate to tropical, with cold winters and mild summers in the northern uplands. The annual rainfall varies from less than 50 mm to more than 400 mm. Owing to the wide agro-ecological diversity, the province has been divided into four agro-climatic zones; namely uplands, coastal, plains and desert (PARC, 1980), and hence the province has the potential to cultivate a wide range of field crops, vegetables and horticulture.

The irrigated agriculture in the province is dependent both on surface and groundwater resources where about 47% of the cultivated area is irrigated, while the remaining 53% is under *sailaba* and *khushkaba* farming (Government of Balochistan, 2009-10). The main sources of surface irrigation are IBIS's Khirther, Pat Feeder and Lasbela canals. Another important source of surface water is the floodwater that flows through streams. Around 30% of floodwater has been harvested for agriculture through *sailaba* diversions, storage dams and minor perennial irrigation schemes. Groundwater is available for irrigated agriculture through *karezes*, springs and tubewells. The total number of tubewells in upland Balochistan is 18,420, which is 53.42% of the provincial total. The tubewell density grew at the rate of 184% during 1971-80, 99% during 1981-90, 40% during 1991-2000, and 64% during 2001-2010 (Government of Balochistan, 2009-10).

Data source and sampling

This study used both primary data and secondary data. A well-structured questionnaire was developed to collect data from the sample respondents. A total of 110 sample respondents, Comprising of 64 tubewell owners, 33 water buyers and 13 rain-fed wheat growing farmers were interviewed face-to-face. A multistage sampling technique was used for the selection of farmers for interview. In the first stage, three key upland basins were purposively selected out of eighteen basins in Balochistan namely Pishin Lora Basin, Nari river Basin and Zhob River Basin. In the second stage, two sample villages within each upland basin were selected randomly. In the third stage, farmers were selected using a proportionate stratified random sampling technique based on matching the proportion of respondents to the proportion of tubewell owners, water buyers and rain-fed crop growing farmers in the overall population.

Multivariate analysis

The study employed both descriptive analyses and econometric models to quantify the key variables. The econometric model used in this study is presented in the proceeding section:

Multiple linear regressions could be used to predict the effect of a number of continuous and/or discrete independent variables on a continuous dependent variable. To see the effect of a number of independent variables on the continuous dependent variable for the wheat productivity analysis multiple linear regression analysis was carried out. The usual method of estimation for regression analysis is Ordinary Least Square (OLS). The parameters of OLS estimates are obtained by minimising the sum of squared residuals. The estimated regression parameters are normalised by subtracting the mean and dividing the estimated standard error, following the t distribution with N-k degrees of freedom. To measure the goodness-of-fit in the multiple regression model, the coefficient of determination R^2 is used. The coefficient of determination R^2 measures the proportion of the variation in the dependent variable explained by the independent variables included in the multiple regression equation. R^2 is often used informally as a goodness-of-fit statistic and compares the validity of regression. Pindyck and Rubinfield (1997) defined R^2 as follows:

$$R^2 = 1 - \sum \hat{\varepsilon}_i^2 / \Sigma (Y_i - \hat{Y})^2$$

The addition of more independent variables to the regression equation can never lower R^2 and is likely to raise it. The interpretation and use of R^2 becomes more difficult when a model is formulated that is constrained to have a zero intercept. In particular, the difficulty with R^2 as a measure of goodness-of-fit is that R^2 pertains only to explained and unexplained variations in Y and therefore does not account for the number of degrees of freedom. A natural solution is to use variances, not variations, thus eliminating the dependence of goodness-of-fit on the number of independent variables in the model (Pindyck & Rubinfield, 1997). The adjusted R^2 is defined as follows:

$$\hat{R}^2 = 1 - \hat{Var}(\varepsilon) / Var(Y)$$

= 1-(1-R2) N-1/N-k

F statistic can be used to test the significance of the R2 statistic in the multiple regression model. The F statistic tests the overall model significance by testing the hypothesis that:

$$H0: \beta 2 = \beta 3 = \ldots = \beta n = 0$$

The alternative hypothesis that at least one of the parameters associated with wheat productivity is different from zero is:

$$H1: \beta 2 = \beta 3 = \ldots = \beta n \neq 0$$

A high value of the F statistic is a basis for rejecting the null hypothesis. SPSS-20 was used to derive the coefficients of the multiple regression models.

Empirical model for estimation of wheat productivity function

To have access to groundwater, it is not compulsory for farmers to be tubewell owners because they can obtain water by purchasing it from other tubewell owners. Those farmers who do not use groundwater can use other sources of irrigation (*Kareze*, spring) or can grow crops under rain-fed conditions. For estimating the impact of tubewell irrigation, the comparison of productivity of tubewell owners and water purchasers provides an estimate of their economic benefits (Bhandari & Pandey, 2006), while the comparison of the productivity of tubewell owners and rain-fed farmers provides the economic value of assured irrigation (Bhandari & Pandey, 2006). Tubewells provide a more reliable water supply, obtained through groundwater markets, to small and landless farmers (Meinzen-Dick, 1996). Likewise, a more reliable water supply not only increases the area and production of crops but also ensures the use of modern inputs such as high yielding varieties, fertilisers, improved seeds, etc. that result in higher yields (Meinzen-Dick, 1996; Shah, 1993).

The effect of different sources of irrigation (either available through owning tubewells or purchasing) on agricultural crop productivity was measured through estimating wheat productivity using the survey (2009) data, and following on from Bhandari and Pandey (2006) & Manjunatha et al. (2011), who compared the returns from irrigated crops with rain-fed crops for evaluating the effect of irrigated water purchased from the groundwater markets. Wheat crops were chosen because they were grown at all locations of the study area, and on own tubewell water, purchased water and as a rain-fed crop which made it easy to compare the productivity difference of the crops grown on irrigation sources (own or purchased) with that of rain-fed crops. The wheat crop inputs use and yield is presented in the following section.

To see the relative importance of the various inputs influencing wheat productivity, the productivity analysis was carried out with the following independent variables:

$$Y= \beta_0 + \beta_1(IRRI)_k + \beta_2(FERT)_k + \beta_3(SEED)_k + \beta_4(FYM)_k + \beta_5(OWNTW)_k + \beta_6(PURWATER)_k + \beta_7(RFED)_k + \varepsilon_k$$

Where: Y is wheat production in kg per acre; IRRI is the number of irrigations applied to wheat crop during a season; FERT is the amount of fertiliser applied in kg per acre; SEED is the quantity of seed applied in kg per acre; FYM is farm yard manure applied in kg per acre; OWNTW is the dummy value for own tubewell (OWNTW = 1 if the water source is own tubewell and zero otherwise); PURWATER is the dummy value for purchased water (PURWATER = 1 if the irrigation source is purchased water and zero otherwise); and RFED is the dummy for the rain-fed crop (RFED = 1 if the crop is rain-fed and zero otherwise).

The above mentioned coefficient measures the absolute change in wheat productivity per unit change in one independent variable holding the others constant. The source of irrigation (through the irrigation source specific dummies) enters as a shift variable - measuring the absolute difference in wheat yields between the different irrigation sources i.e., wheat grown with water from farmer's own tubewell as the source of irrigation, wheat grown with purchased water and wheat grown with rain water. The irrigation source specific dummies mainly capture the effect of irrigation source specific factors other than the above included in the estimation (such as water source reliability, quantity of groundwater markets and farm income).

Results and Discussion

This section presents the results derived from the data analysis. It presents the demographic and socio-economic characteristics of sample respondents, sources of irrigation, payment methods prevalent in the study area, inputs used in wheat production and empirical model for wheat productivity. In the end remedial measures for improvement are presented.

Demographic and socio-economic characteristics of sample respondents

The analysis of the demographic and socio-economic characteristics of the households, such as average age, income, education level, employment sources, distance to market and its location helps understand the population of interest (Mushtaq, 2004). The results are presented for the size of landholdings and cropping patterns that have a direct relationship with groundwater use.

Family size and composition

The study area is characterised by large family sizes as joint family systems prevail there and this is shown by the fact that the maximum family size varies from 65 to 95 at different locations of the study area. The existence of such large families is not an exception in the study area. These large families prefer to live together for security and other reasons and cook in a common kitchen. They jointly manage their agricultural properties and have the advantage of a lot of family labour. Moreover, as a family unit, they are wealthier than the other average families and usually own a large number of tubewells. Table 1 shows the descriptive statistics of the family members and adult family members that are mainly the working members of the family.

Age

The age variable is usually used as a proxy for measuring the farming experience of sampled respondents. Age, years of schooling and farm experience of the household head are considered to be most pertinent in framing farmers' perceptions (Mushtaq, 2004). Table 2 depicts the distribution of sample respondents according to average age in the study area. The results shows that the majority of respondents belonged to the experienced age groups between 26-55 years, while the younger (< 25 years) and older (> 56 years) age groups were 4.64% and 15.8% respectively, comparatively less in proportion to the others.

Table1: Descriptive statistics of family size, adult family members and age

	Mean	Minimum	Maximum	STD*
Family size ** (#)	22.19	3.33	76	
Adult (> 18 years) members	10.57	2	42.67	7.56
Age (years)	42.09	20.69	78.73	20.69

Source: Survey (2009) * Standard deviation ** The family means a group of people living under one roof and doing joint cooking. The family size was found very large due to the extended family system prevailing in the study area and its typical socio-cultural conditions.

Table 2: Altitude-wise distribution of respondents according to age groups (Frequency)

	< 25 years		26-40 years		41-55 years		>56 years	
	N	%	N	%	N	%	N	%
Age	16	4.64	136	40.2	133	39.36	54	15.8

Source: Survey (2009)

Education

The educational level of a population helps in judging the quality of human resources and the development stage of the society (Mushtaq, 2004). Mushtaq (2004) further argued that the literacy status of the farmers is an important variable which influences the farmers' resource allocation efficiency and adoption of new technology. Moreover, the education level shows the human resource development position of a community. The literate respondents are more likely to be more efficient farmers (Bahadur, 2004). Similarly the better educated respondents are more likely to adopt modern technologies and use modern techniques (Mushtaq, 2004). The results show that the overall literacy level was around 65%. Among the literate farmers, the highest proportion had primary education, followed by secondary, intermediate, then graduate and post graduate. The higher education levels (graduate and post graduate) were found among 11 to 14 % of sampled respondents at the various locations of the study area.

Sources of irrigation

The major source of irrigation in all locations of upland Balochistan was tubewells (91%). The other sources of irrigation such as K*arezes and* springs (5%), while dug well were (4%). *Karezes* and springs were more viable in the high uplands. While at the low and medium altitudes their share in the overall irrigation sources was insignificant.

Payment Methods

The two methods of payment for water reported are in cash and payment in kind as a certain share of crop output. Payment in kind as a share of crop output varies from 33% to 66% of crop output. Moreover, water rates vary and are influenced by water scarcity, energy source and charges, pump capacity, power tariffs, productivity-related factors and cropping patterns.

Wheat inputs use and yield estimates at various water sources

The purpose of this analysis is to estimate wheat productivity with different sources of irrigation to wheat grown as a rain-fed crop. The inputs use and average wheat yield of wheat irrigated by own tubewell, purchased water and rain-fed are presented in Table 3. The inputs such as fertiliser, farmyards manure (FYM) and water was used in a more appropriate quantity in the irrigated wheat areas than in rain-fed wheat areas due to the complementary use of the inputs with water. Yield per acre was found highest for those farmers having their own tubewells as a source of irrigation, followed by purchased water and then rain-fed. The obvious reason was the reliable and timely availability of groundwater either through their own tubewell or through water markets. However, the yield of rain-fed wheat crops was found to be significantly less than irrigated wheat, due to moisture stress mainly because of the erratic and scanty rainfall.

Table 3: Major inputs use in wheat production

	Owned tubewell water	Purchased water	Rain-fed
N	64	33	13
Inputs			
Yield (kg/acre)	1,048	924	307
Seed (kg/acre)	49.10	51.15	49.42
Fertilisers (kg/acre)	54.62	40	15.72
FYM (kg/acre)	702.33	588	524
Irrigation (number)	4.08	3.79	----

Source: Survey (2009)

The difference in yields showed a difference of 124 kg per acre between the yields of wheat irrigated by owned tubewells and wheat irrigated by purchased water. But the more significant difference in wheat yield was between that grown on owned tubewell water versus the rain-fed crop which comes to 741 kg/acre while that of purchased water versus rain-fed was 617 kg/acre (Table 3). The yield difference is shown by Figure 1.

The above mentioned yield difference in favour of tubewell owners is most probably due to the greater control of the water source that tubewell owners have.

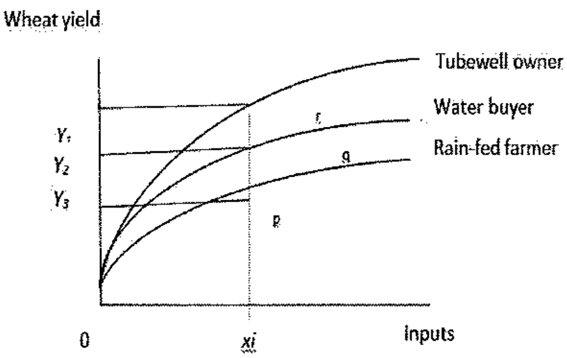

Figure 1: The hypothesised effect of tubewell irrigation on wheat productivity

The water buyer was able to get a reasonable yield (more than the provincial average yield of 859 kg/acre) due to their ability to buy water. Water non-buyers on the other hand had very low yields. The effects of different inputs on wheat yield are presented in the following section (Table 4).

Table 4: Difference of average yields (kg per acre)

Irrigation source	Difference
Difference between owned tubewell water and purchased water wheat yields	***124
Difference between owned tubewell water and rain-fed wheat yields	***741
Difference between purchased water and rain-fed wheat yields	***617

Source: Survey (2009) ***, **,* means significance at 1, 5 and 10 % respectively.

Empirical Model for Estimation of wheat productivity

To see the relative importance of the various irrigation sources and the inputs influencing wheat productivity, productivity analysis was carried out for the inputs given in Table 3. The following empirical model was estimated with a set of independent variables.

$$Y = \beta_0 + \beta_1(IRRI)_k + \beta_2(FERT)_k + \beta_3(SEED)_k + \beta_4(FYM)_k + \beta_5(OWNTW)_k + \beta_6(PURWATER)_k + \beta_7(RFED)_k + \varepsilon_k$$

Where:

Y is wheat production in kg per acre;

IRRI is the number of irrigations applied to the wheat crop during a season;

FERT is the amount of fertiliser applied in kg per acre;

SEED is the quantity of seed applied in kg per acre;

FYM is farm yard manure applied in kg per acre;

OWNTW is the dummy value for owning a tubewell (OWNTW = 1 if the water source is from an owned tubewell and zero otherwise);

PURWATER is the dummy value for purchased water (PURWATER = 1 if the irrigation source is purchased water and zero otherwise); and

RFED is the dummy for the rain-fed crop (RFED = 1 if the crop is rain-fed and zero otherwise).

The above mentioned coefficient measures the absolute change in wheat productivity per unit change in one independent variable holding the others constant. The source of irrigation (through the irrigation source specific dummies) enters the production function as a shift variable measuring the absolute difference in wheat yields between the different irrigation sources i.e., wheat grown by tubewell owners using their own tubewell as the source of irrigation, wheat grown on purchased water and wheat grown on rain water. The irrigation source specific dummies mainly capture the effect of the irrigation source specific factors other than those included in the production function (such as water source reliability, quantity, etc.). The multicollinearity test showed that the multicollinearity problem doesn't occur (Table 5). Moreover, to see the robustness of the model, diagnostic tests were conducted by adding and dropping variables and it was found to be insensitive to these.

Table 5: Correlation matrix of factors affecting wheat productivity

Variable	Irrigwhtowntw	Rfedwht	Irrigwhtpurwat	Irrino	Fertiliser	Seed	Manure
Irrigwhtowntw	1.000	-0.425	-0.530	0.476	0.269	-0.074	0.210
Rfedwht	-0.425	1.000	-0.247	-0.590	-0.257	-0.016	0.014
Irrigwhtpurwat	-0.753	-0.247	1.000	0.120	-0.100	0.128	-0.176
Irrino	0.476	-0.590	0.120	1.000	0.336	0.048	0.043
Fertiliser	0.269	-0.257	-0.100	0.336	1.000	0.172	0.076
Seed	-0.074	-0.016	0.128	0.048	0.172	1.000	-0.001
Manure	0.210	-0.014	-0.176	0.043	0.076	-0.001	1.000

The results of the estimated equation are shown in Table 6. Fertiliser and organic manure (FYM) have strong positive effects on the wheat yields. The irrigation number and seed rate are also positively related with higher wheat yields. The results showed that wheat productivity changes in the following way with the effect of different inputs:-

(i) with each additional irrigation, wheat productivity increases by around 38.26 kg/acre;

(ii) with each additional kilogram of fertiliser use, the wheat productivity increases by 2.74 kg/acre;

(iii) increasing the seed rate by 1 kilogram per acre decreases the wheat yield by 2.096 kg/acre, and

(iv) an additional 1 kilogram of farm yard manure increases wheat productivity by 0.033 kg/acre.

The irrigation source specific dummy for owned tubewell (OWNTW) shows that average yields taken by tubewell owners are greater than purchased water and rain-fed wheat yields by 124 and 741 kg/acre respectively.

Table 6: Estimated regression coefficients of the effect of various irrigation sources on wheat yield in upland Balochistan, 2009

Variable	Coefficient	t statistics
(Constant)	***638.596	3.182
OWNTW	178.671	1.196
RFED	-296.805	-1.543
PURWATER	149.648	1.016
IRRI	38.265	1.377
FERT	***2.740	7.536
SEED	-2.096	-.896
FYM	**.033	2.338

N= 97, R^2 = 0.80, *, **, *** means significance at 10, 5 and 1% respectively.
Dependent variable: Yield in kg per acre
Source: Survey (2009)

The reason for this productivity difference in favour of tubewell owners is probably the availability of timely and reliable groundwater from their own tubewell. The dummies for purchased water (PURWATER) and rain-fed (RFED) irrigation sources suggest that yields of purchased water are greater than rain-fed wheat yield due to the access of water buyers to irrigation water as compared to rain-fed farmers. The wheat crop productivity gap between tubewell owners, water buyers and water non-buyers shows the importance of tubewell irrigation and groundwater markets, and their impact on crop productivity.

The future of agriculture in the upland of Balochistan depends on the sustainable use of groundwater being the major irrigation source. In future the tubewells development may be allowed only in those areas having potential for development. The existing tubewells may be regulated in terms of pumping. The following section present some measures from the literature for the improvement in the efficient water use:

Improving water use efficiency for sustainability

To improve the efficient water use Halcrow Pakistan and Cameos Consultants (2008) suggested the downward revision of electricity subsidies on tubewells, replacement of high delta crops with low delta crops; and restrictions on the installation of new tubewells. While Barker et al., (2000) suggested that, to meet the demand for high value water uses such as domestic, industry and hydropower and in order to meet the ever increasing demand for food under the increasing water scarcity situations, the agriculture sector must produce more food with less water through becoming water efficient in canal irrigation systems, better management of groundwater and surface water, and assessing the potential of alternative low cost micro-irrigation technologies in water-scarce rain-fed areas. Sahibzada (2002) suggested that the efficient water use in agriculture sector needs to be given urgent attention because it is the major user of water. Moreover, water being an un-priced commodity for agriculture purposes in many parts of the world, is used without great care, and giving water a price will help ensure its value and efficient use. He further argued that inadequate attention has been given to devising a mechanism for pricing of irrigation water to its users and he considers reviewing the level and form of water charges in the past as an important way of increasing efficient water use through improving water allocation. Because there is little room for building new dams in Pakistan, water use efficiency needs to be increased through the introduction of an appropriate water pricing system to replace the existing supply-based irrigation system with a demand-based system.

Similarly, Ellis (1992) argued that to improve efficient water use farmers should be charged a price per litre for the volume of water used, adequate to cover operating costs and to provide a rate of return for the investment. This in turn would make farmers more efficient in water use and would use water only up to the point where the marginal return on water use equalled the price per litre farmers pay for water. As a result a proper market for irrigation water would be created and efficiency ensured. Water markets already exist in many parts of the world, but improving the market outcome is still a challenge with respect to efficiency and equity. Contrary to them in another study Qureshi et al. (2009) argued that in Pakistan, due to the large number of small users, techno-institutional approaches such as introducing water rights, direct or indirect pricing and permit systems wouldn't be successful. They suggested instead water demand management through the adoption of water conservation technologies, revision of existing cropping patterns, exploration of alternate water resources and supply management through the implementation of the groundwater regulatory frameworks developed by Provincial Irrigation and Drainage Authorities (PIDAs) and the introduction of institutional reforms to enhance effective coordination.

Conclusion

The results showed that average yields taken by tubewell owners were greater than yields taken by water buyers and rain-fed wheat yields by 124 and 741 kg/acre respectively. The comparison of productivity of tubewell owners and water purchasers provides an estimate of their economic benefits, while the comparison of the productivity of tubewell owners and rain-fed farmers provides the economic value of assured irrigation. In other words, the productivity gap between tubewell owners, water buyers and water non-buyers shows the importance of tubewell irrigation and water availability from water sellers and their effects on overall crop productivity.

The findings of the study have many implications. The preceding analysis results shows that tubewells are providing reliable access to irrigation water hence enhance the overall crop productivity and help reduce poverty. Electricity for tubewells has been subsidized for many years that helps keep moving the wheels of the agriculture economy of upland Balochistan. The results also show that the subsidy benefits are not merely restricted to tubewell owners, instead are redistributed to water buyers and many others who are many times more in number than tubewell owners.

For a sustainable groundwater use, as recommended by Mushtaq et al. (2014), the demand side groundwater management that should include a rational pricing for efficient water use; replacement of water demanding crops water-use efficient crops; and the adoption of modern water-saving irrigation techniques and practices are suggested. Moreover, the institutional factors such as defining water use rights, a more rational power pricing policy can help in water demand management. While the availability of institutional credit facilities to the farmers can play an important role in the groundwater development in the potential aquifers.

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