Estimating groundwater extraction cost and its efficiency use in dates production in Riyadh region, Saudi Arabia

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Othman S. Nashwan
Instituição: King Saud University
Endereço: Department of Agricultural Economics. College of Food and Agricultural Sciences, Riyadh 11451, Saudi Arabia

Mohammad H. Al-Qunaibet
Instituição: King Saud University
Endereço: Department of Agricultural Economics. College of Food and Agricultural Sciences, Riyadh 11451, Saudi Arabia

Adel M. Ghanem
Instituição: King Saud University
Endereço: Department of Agricultural Economics. College of Food and Agricultural Sciences, Riyadh 11451, Saudi Arabia
E-mail: aghanem@ksu.edu.sa

Abstract

This article was set to estimate the extraction costs of groundwater and its efficiency use in producing dates in Riyadh Region, Saudi Arabia. This was achieved through the estimation of capital inputs and operational costs for each unit of water (cubic meter M^3) used to produce dates. Also, the production function for dates was estimated to measure water economic efficiency in dates' production. This study used data collected from a random sample of date palm farmers in Riyadh Region in 2015. Results showed that: (1) The cost of extracting groundwater increases as the depth of drilling for wells increases. Using a 15% discount value, the cost of extracting groundwater increased from 0.436 Saudi Riyals (SR)/M^3 for 100 meters deep wells to 0.658 SR/M^3 for 200+ meters deep wells. (2) a 10% change in irrigation water, labor, and fertilizers results in a positive change in dates production of 4.8%, 0.8%, and 0.4%, respectively. (3) Marginal return for irrigation water used for dates production was estimated to be 699 SR/1000 M^3. (4) The use of groundwater was economically efficient because the value of marginal product of water (VMP) was greater than its marginal cost (MC) of extraction. (5) Given the scarcity of water in Saudi Arabia, this study stresses the need to include the "economic value" of irrigation water of date palms in order to conserve water.

Keywords: Cost of extracting. Groundwater. Wells. Economic efficiency. Dates.

1. Introduction

Saudi Agriculture depends mainly on groundwater due to its desert climate and the lack of rivers and lakes. As of 2013, the cumulative number of licensed groundwater wells in Riyadh Region was 64,690. Date palms occupy a very important role in Saudi agriculture for many centuries. The area of date palms is about 156,900 hectares constituting 22.6% of total Saudi agricultural land. Riyadh Region is one of most important dates' producing regions in Saudi Arabia accounting for 30.8% of total dates production in 2013 (Ministry of Agriculture, 2014). The Saudi production of dates was 1.09 million tons in 2013, of which 999,600 tons were consumed locally, which means 109.5% self-sufficiency in dates. However, date palms consume a lot of irrigation water amounting to about 27,660 M^3/hectare (Al-Qunaibet et al., 2014).

Singh et.al. (2006) found that there are significant differences in the value of marginal product (VMP) of water unit in five different farms in Sirsa, India. They found that VMP of water differs from one farm to another, and between crops grown. Al-Ruwais (2008) tried to price agricultural inputs according to their elasticities the derived from agricultural production functions in Saudi Arabia. He found that cost of water unit to be 0.15 SR/M^3 in 2005. Ghanem and Nashwan (2009) estimated the return and economic cost for using water resources in some agricultural exports in Saudi Arabia. They found that the value of water compared to the economic value of some vegetable and fruits exports during the period 2003-2007 to be between 3.59% for tomatoes and 24.63% for dates. Al-Qunaibet, et al. (2014) found that the inclusion of the cost of water needed to produce fresh milk will increase milk production costs in small, medium, and large dairy farms by 10.03%, 8.72%, and 9.04%, respectively.

This paper will estimate the cost of extracting groundwater and its economic efficiency use in date palms production in Riyadh Region, Saudi Arabia, by fulfilling the following objectives: (1) Estimating groundwater extraction cost from different depths, (2) Estimating dates production function, (3) Estimating the marginal revenue and economic efficiency for groundwater used to produce dates.

2. Methodology

A random sample of 50 date palm farms was selected to calculate: (1) Capital inputs needed for ground water extraction, namely: wells, pipes, electric motors, water pumps, cables, and electric switches; (2) Variable or operational costs, namely: electric power bills, and annual maintenance), and (3) The amount of water pumped annually. Then, the following economic equations were used:

- Capital Recovery Factor = (1 ÷ Total present values of fixed values at a specified discount rate);
- The annual installment of Capital Asset Costs = construction costs of capital assets × Capital Recovery Factor;

- Average Capital Assets per unit of water = (annual installment of capital assets ÷ amount of groundwater withdrawn annually);
- Average Operating Costs per unit of water = (operating costs ÷ amount of groundwater withdrawn annually);
- Total Costs of Extracting groundwater = Average Capital Assets per unit of water + Average Operating Costs per unit of water.

To fulfill the abovementioned objectives, econometric analysis was used to estimate the production function for dates in Riyadh Region using the following form:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + e$$

where:

Y Quantity of dates produced (in tons).

X_1 Irrigation water for dates palms (in thousand M^3).

X_2 Labor (man/day).

X_3 Chemical fertilizers (in tons).

a, b_1, b_2, b_3: Parameters (coefficients).

e_i Random error.

3. Results and Discussion

3.1. Extraction costs of groundwater from various depths

The variables expected to affect the extraction costs of ground water are the capital assets cost needed to extract water (water well, pipes inside the well, motor, pump, cables, electric switches), expected life of well, operating costs (electricity consumption and maintenance), and the amount of water extracted annually. Table (1) shows that the cost of extracting groundwater increases as the well's depth increases. And at a 15% discount rate, groundwater extraction costs increased from 0.436 SR/M^3 for wells less than 100 meters deep to 0.68 SR/M^3 for wells 200 meters deep and more, which means that the cost of extracting groundwater increased by 50.9% from 100 meter depth to +200 meter. Table (2) shows that increasing discount rate from 5% to 15% will increase the total cost of extracting groundwater from 0.502 SR/M^3 to 0.658 SR/M^3.

Table 1: The average cost of capital and operating assets for extracting groundwater from various drilling depths in the Riyadh Region, Saudi Arabia.

Item	Depth of Groundwater Wells (Meters)			Well's Life Span (years)
	< 100	100 - 200	200+	
Total Cost of Drilling Groundwater Well ('000 SR)	92.9	127.8	150.4	30
Electric Motor ('000 SR)	9.0	15.0	25.0	5
Water Pump ('000 SR)	11.0	16.0	20.0	5
Pipes inside the Well ('000 SR)	1.8	3.0	5.0	10
Electric Cables ('000 SR)	7.0	14.0	25.0	15
Electric Switches ('000 SR)	3.5	6.0	15.0	20
Annual Cost of Electricity Consumption ('000 SR)	12.0	24.0	30.0	-
Annual Maintenance Costs ('000 SR)	2.0	4.0	6.0	-
Annual Amount of Water Extracted (M^3)	82.2	108.87	120.4	-

Source: Calculated from the data obtained by the questionnaire collected in 2015.

Table 2: Average Cost of Extracting Groundwater from Different Depths of Wells in Riyadh Region, Saudi Arabia.

Item	Capital Recovery Factor	Annual Installment Cost for Different Wells' Depths ('000 SR)			Extraction Costs (SR/M^3)		
		< 100 Meters	100-200 Meters	200+ Meters	< 100 Meters	100-200 Meters	200+ Meters
Groundwater Extraction Costs at 5% Discount Rate:							
Construction Costs of the Groundwater Well	0.065	6.04	8.31	9.77	0.073	0.076	0.081
Electric Motor and Water Pump	0.231	4.62	7.16	10.39	0.056	0.066	0.086
Pipes inside the Well	0.130	0.23	0.39	0.65	0.003	0.004	0.005
Electric Cables	0.096	0.67	1.34	2.40	0.008	0.012	0.020
Electric Switches	0.080	0.28	0.48	1.20	0.003	0.004	0.010
Electricity Costs	-	12.0	24.0	30.0	0.146	0.220	0.249
Annual Maintenance Costs	-	2.0	4.0	6.0	0.024	0.037	0.050
Total Costs of Extracting Groundwater (SR/M^3)					**0.314**	**0.420**	**0.502**
Groundwater Extraction Costs at 10% Discount Rate:							
Construction Costs of the Groundwater Well	0.106	9.85	13.55	15.94	0.120	0.124	0.132

Electric Motor and Water Pump	0.261	5.22	8.09	11.75	0.064	0.074	0.098
Pipes inside the Well	0.162	0.29	0.48	0.81	0.004	0.004	0.007
Electric Cables	0.131	0.92	1.83	3.28	0.011	0.017	0.027
Electric Switches	0.117	0.41	0.70	1.76	0.005	0.006	0.015
Electricity Costs	-	12.0	24.0	30.0	0.146	0.220	0.249
Annual Maintenance Costs	-	2.0	4.0	6.0	0.024	0.037	0.050
Total Costs of Extracting Groundwater (SR/ M^3)					**0.374**	**0.482**	**0.578**
Groundwater Extraction Costs at 15% Discount Rate:							
Construction Costs of the Groundwater Well	0.150	13.94	19.17	22.56	0.170	0.176	0.187
Electric Motor and Water Pump	0.291	5.82	9.02	13.10	0.071	0.083	0.109
Pipes inside the Well	0.196	0.35	0.59	0.98	0.004	0.005	0.008
Electric Cables	0.169	1.18	2.37	4.23	0.014	0.022	0.035
Electric Switches	0.158	0.55	0.95	2.37	0.007	0.009	0.020
Electricity Costs	-	12.0	24.0	30.0	0.146	0.220	0.249
Annual Maintenance Costs	-	2.0	4.0	6.0	0.024	0.037	0.050
Total Costs of Extracting Groundwater (SR/ M^3)					**0.436**	**0.552**	**0.658**

Source: Calculated from Data in Table (1).

3.2. Dates production function in Riyadh region

Production of dates in Saudi Arabia is affected by the following economic factors: (1) Irrigation water, (2) Labor, and (3) Fertilizers. Using multiple regression procedure and the double logarithmic model for dates' production function in Riyadh Region resulted in the following production function**:**

$$Ln\,Y = 0.864 + 0.48 Ln X_1 + 0.08 Ln X_2 + 0.04 Ln X_3$$

$$(3.64)^{**} \quad (2.83)^{*} \quad (3.12)^{**} \quad (9.82)^{**}$$

$$R^{-2} = 0.81 \quad F = 87.77$$

** significant at level 1%.
* significant at level 5%.

This estimated production function shows that the production elasticity for water (X_1), agricultural labor (X_2), and fertilizers (X_3) to be 0.48, 0.08, and 0.04, respectively. This means that a 10% change in water quantity, agricultural labor, and fertilizers will result in a change in the same direction by 4.8%, 0.8%, and 0.4%, respectively.

The coefficient of determination (R^{-2}) was estimated to be 0.81, which means that the three independent variables (X_1, X_2, X_3) explain 81% of the changes in dates production.

The estimated double logarithmic model was found to be a good fit since Theil's Inequality Coefficient (U-Theil Test) is close to zero (= 0.09), and free from Heteroskedasticity problem according to The White Test with an F value of 1.5 which was insignificant at 5%.

3.3. Marginal revenue for dates' irrigation water

From the estimated dates production function:

$$Y = 2.373\, X_1^{0.48}\, X_2^{0.08}\, X_3^{0.04}$$

We can derive the marginal product for water (MP_1) as follows:

$$MP_1 = \frac{dY}{dX_1} = 1.139\, X_1^{-0.52} X_2^{0.08} X_3^{0.04}$$

And using the average agricultural labor used (X_2 = 40.11 man/day), and the average quantity of fertilizers used (X_3= 6.79 tons), we get:

$$MP_1 = \frac{dY}{dX_1} = 1.139\, X_1^{-0.52}\, (40.11)^{-052}\, (6.79)^{0.04} = 17.348\, X_1^{-0.52}$$

And with an average sale price for dates (P_y= 10.5 thousand SR/ton) and average amount of irrigation water (X_1= 480.48 thousand M^3), the value of the marginal product for dates of water (VMP_1) will be 699 SR/1000 M^3, or SR 0.699 per cubic meter of irrigation water:

$$VMP_1 = \left\{\frac{dY}{dX_1}\right\} * P_Y = \{17.348\, X_1^{-0.52}\} * 10.5$$
$$= \{\, 17.348\, (480.48)^{-0.52} \} * 10.5 = 699 \text{ SR/1000 } M^3$$

3.4. Economic efficiency for water used to produce dates in Riyadh region

The economic efficiency for a resource (input) will be achieved when the marginal revenue (MR) equals marginal cost (MC) of this input. However, irrigation water in Saudi Arabia has no pre-set value by the government, thus the cost of extracting groundwater will be used to represent the marginal cost of irrigation water to grow date palms and produce dates in Riyadh Region. Table (3) shows that using a 15% discount rate, the marginal revenue relative to the marginal cost of dates' irrigation water will be 1.6, 1.27, and 1.06 for wells less than 100 meters deep, 100-200 meters deep, and 200+ meters deep, respectively.

4. Recommendations

It is a well-known fact that Saudi Arabia is a desert country with no rivers or lakes and very little precipitation. The agricultural sector gets its irrigation water from non-renewable deep groundwater aquifers, which were seriously depleted during the last forty years to grow wheat and fodder and other crops. Therefore, sustainable agricultural development requires very serious conservation effort to preserve the groundwater aquifers and use them very wisely. Thus, the government must include a value or price for irrigation water when estimating the benefit-cost of agricultural development and expansion.

Table 3: The economic efficiency of groundwater use in the production of dates in Riyadh.

Item	Well's Depth (Meters)		
	< 100 Meters	**100 – 200 Meters**	**200+ Meters**
Marginal Revenue for Water (SR/ '000 M^3)		699	
Marginal Cost (Cost of extracting groundwater, SR/ '000 M^3):			
Costs of extraction at 5% discount rate	314	420	502
Costs of extraction at 10% discount rate	374	483	578
Costs of extraction at 15% discount rate	436	552	658
Economic Efficiency (ratio of Marginal Revenue to Marginal Cost):			
Rate of Return relative to Marginal Cost at 5% discount rate	2.23	1.66	1.39
Rate of Return relative to Marginal Cost at 10% discount rate	1.87	1.45	1.21
Rate of Return relative to Marginal Cost at 15% discount rate	1.60	1.27	1.06

Source: Calculated from data in a Table (2) and the estimated marginal yield function of water in this study.

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