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Economic Efficiency Modelling of Water Resources in the Kingdom of Saudi Arabia

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Abstract:
Water is one of the most precious and valuable resources in the world generally and in Saudi Arabia specially. Situated in the tropical and sub-tropical desert region with arid climate, the Kingdom of Saudi Arabia (KSA) is exposed to dry winds and limited water resources .Therefore, the scarcity of fresh water resources poses a major challenge and affects the Saudi development plans since they realized that their supply of freshwater cannot be taken for granted. Moreover, the demand for fresh water is increasing because of population growth and household consumption pattern.

This paper indicates that the Water crisis in Saudi Arabia should be a top priority for the government, since it will affect the country on all levels. It also stresses the importance of Integrated Water Resources Management (IWRM) as the solution to this crisis, using long term water demand model to show the benefits of regulating the water demand for the agricultural sector since it constitutes more than 80% of the total water demand. But this does not undermine the effect of domestic or industrial water demand, since such demand for water will soon increase due to the constant increase in the population growth rate.

Historical data was analyzed to create a predictive model, this model showed that agricultural water was mostly affected by three major factors which are alfalfa, sorghum production, and the cultivated land. The analysis also showed that the specific effect of each one of those factors on the agricultural water demand by using the concept of demand elasticity.

In conclusion, fresh water is a finite resource that is becoming scarce. While it's true that water is constantly being recycled through the Earth's water cycle, people are using up the planet's fresh water faster than it can be replenished.

Keywords:
Water, Agricultural sector, Saudi Arabia, Scarcity, Predictive model.

JEL Classification Codes:
C5; Q2; Q14; Q15; R14

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Introduction

Global View on Water Resources

The world is increasingly turning its attention to the issue of water scarcity since global changes, including environmental change, rising population, declining ecosystems, and unplanned urbanization are drastically increasing the risks of water-related disasters. Many countries consider water scarcity as a basic challenge to their economic and social development.

Water is closely related to economic growth and development since it is tied to food provision and trade (agriculture and industry). Therefore policy makers, civil society and the business sector around the world are becoming more and more aware of the challenges facing global water resources, and the need to cautiously manage these resources; however, the progress has been limited, and overall too slow.

The following estimations show the global state of water withdrawal in 2030 for the agricultural and the industrial sectors (Thunell 2012):

- The Agricultural Sector:

Today 's Agriculture accounts for 71% of global water withdrawals (a total of 3,100 billion m^3), In 2030, it is estimated to increase to 4,500 billion m^3, this growth will come primarily from including withdrawals from the Indian projected withdrawals that account for 1,195 billion m^3 , the Sub-Saharan Africa 820 billion m^3, and China 420 billion m^3.

- The Industrial Sector :

Today industry represents 16% of global demand, estimated to increase to a projected 22% in 2030. The growth will come primarily from China (where industrial water demand is projected at a level of 265 billion m^3).

Furthermore, it is estimated that by 2030, under an average economic growth scenario and with no efficiency gains, global water necessities would grow from 4,500 billion m^3 to 6,900 billion m^3. This constitutes 40 % more than the present available supply. One-third of the population, concentrated in developing countries, will live in water deficiency greater than 50%.

So water is not only a key factor for economic development, it is also crucial for social development. Water scarcity can cause migration, refugees, and many other situations where basic human rights are endangered, and finally water has a basic and a fundamental function in maintaining the natural environment. Therefore, policy makers across the world, in the public as well as in private sectors, must make difficult and careful decisions on water allocation.

Water Resources in the Middle East

Water in the Middle East region is considered a very rare resource with very few renewable sources. More than 75% of those limited renewable sources are being overused, making its extraction rate the highest rate per capita in the world (804 cubic meters per year). The Middle East also contains the largest and most developed water storage than any other similar region.

As a result of the increase in population growth rate and the continuous growth in the economy, the region will witness an upward increase in demand. The highest water consuming sector in the entire Gulf region where oil companies are still dominating, is the agricultural sector, although it only accounts for a tiny part of the GDP (below 3% of national GDP in numerous cases),but it is the greatest user of water resources.

The Middle East can be divided into three fractions that have similar but also unique characteristics from a regional point of view. The three fractions are:

1-The first fraction is the Jordan River Basin which includes Syria, Palestine, Jordan and Lebanon.

2-The second fraction is the Euphrates and Tigris River Basin passing through Syria, Iraq, Iran and Turkey.

3-The third and last fraction is the Gulf States on the Arabian Peninsula accounting for all of Yemen, UAE, KSA, Bahrain, Qatar, Oman, and Kuwait.

Due to the scarcity of water in the Middle East, it is of major importance to develop and control water consumption from both political and strategic perspectives. Although having the highest water extraction rates, this region still witnesses the lowest per capita accessibility, and additional water storage facilities are being built at a rate greater than that of any region around the world. However, the availability and consumption of water is still a vital need for millions of people to escape poverty; therefore, water consumption will increase with the decrease in poverty. But there are other causes that may further raise the demand for water; the fast growing consumptive population is one of the most important reasons. The continuing climate change makes up for such worries in other countries in the world, but it is not the case in the Middle East where climate change projections show a decrease in the accessibility level of water in the region, although it is most needed in such areas. Therefore, the Middle East has become a major importer of food from other countries around the world, but even in such countries, agriculture is threatened by the climate change, and the decline in food production.

Even political parties in every country in the Middle East realize the significance of water in the process of development. The relation between countries and natural resources has become a robust one. Every resident of the Middle East recognizes the necessity of water that preserves life, develops and boosts agriculture. It also improves the overall health and well- being.

One of the most important water policies in the Middle East was the overall improvement of the irrigational networks, and the adoption of good water management strategies to boost economic growth. Therefore, the subject of preserving water has become a main challenge to every nation in the region. It is a challenge that may lead to either a clash or collaboration.

However, the implications that will occur in the years to come won't be limited to the water problem currently facing the region. But, to the efficiency of controlling the current accessibility of water sources of the Middle East i.e. the Euphrates- Tigris basin, common ground aquifers, and the Jordan basin which will aid the region to address the importance of water in economic growth and development.. So in order to attain both political and water security for current and future Middle East residents, the region must achieve more control over water consumption and water governance.

Cooperative and efficient interventions are most needed to target the scales of water use on both, the regional and the national levels. Other important policy actions would be to increase investment in the energy sector in order to improve the control of water production and desalination.

In addition, pumping money to adapt to climate change and to keep the current level of service running at the basin is vital to guarantee more water supplies in the long run. Keeping in mind the function of water in the region, interventions targeting growth should take more than one sector into consideration. Thus, the results will allow the national economies to boom and realize growth by decreasing poverty not only in the Middle East region, but all over the world.

There are currently serious collaborative measures in the region taking the form of organizations that target numerous forms of growth obstacles; such organizations include the Arab Water Council, the Arab League, and the Gulf Cooperation Council.

Sub-regional descriptions.

The Euphrates and Tigris River Basins:

The Euphrates basin has a surface area of 450,000 Km^2, which is shared by Iraq, Syria and Turkey, and this river is 2,735 km long. The mediocrity of the irrigation activities left the land in the basin in dreadful conditions, i.e.; a study by the United Nations Environment Program (UNEP 2008) indicates that 30% of this land has been spoiled due to poor irrigation practices. Re-flooding the land is a solution that is being worked on currently, in order to renovate the area and repair the current status of the ecosystem.

The Jordan River System or JRS:

The JRS contains many hydrological inputs. Its basin is considered of major importance to Palestine and Jordan, while Lebanon and Syria depend much less on it. The river, however, suffers from many problems which include the excess rate of extraction, the presence of serious pollution issues, and the salinity that creates a serious problem in the dry seasons. Only a minimal portion of the Jordan River's Flow is attaining the Dead Sea. This causes numerous serious ecological and social issues which include sink holes that cause a retreat in the sea level. The flow has been recorded through history at 1.3 billion cubic meters per year, but now it has declined to a hundred million cubic meters per year.

Arabian Peninsula

Most of the resources in the region are in the form of groundwater which is over-extracted because 5 out of 7 countries consume water from it at a larger scale than normal recharge. This over-extraction of groundwater was the main cause of salt water invasion in the aquifers, thus causing a decrease in water tables, and consequently greatly decreasing agricultural productivity.

Table 1.Precipitation and water use in a selected number of countries in the Middle East (TARWR: Total Actual Renewable Water Resources)

Country	Precip. mm/yr	Total use % TARWR	Population (1 000 000s)	TARWR Per Capita (2005) m3/yr
Iran	200	53	69,788	1 970
Iraq	200	57	25,856	2 920
Israel	400	122	6,560	250
Jordan	100	115	5,614	160
Kuwait	100	2 227	2,595	8
Oman	100	137	2,935	340
Saudi Arabia	100	722	24,919	96
Syria	300	76	18,223	1 440
Turkey	600	18	72,320	2 950
UAE	100	1 538	3,015	49

Source: SIWI 2009

To help solve the water issue, the nations which are rich in oil resources on the Peninsula have begun huge desalination projects. Desalination projects are the major providers of drinking water in Saudi Arabia with about 70% of water production. All nations on the Peninsula are consuming more than a 100% of their renewable water sources, reaching more than two thousand percent in Kuwait. Thus, with the predictions of the change in climate and the continuous rise in demand, it is required to begin controlling water consumption. New water control schemes are required, i.e., increasing awareness and improving water taxes. In addition, new water governance policies should include better water tariff systems and increased awareness.

Water used for agriculture

More than 85% of the extracted water in the region is used for agricultural purposes. But the fact changes from one nation to another, the largest consumers are Iran, Saudi Arabia, and Iraq that go beyond 90%, while only the Palestinian occupied territories (63%) and Turkey are under this level. The Middle East is very responsive to climate change due to the negative effects on the agricultural sector and the lack of security in the region. The countries of the Middle East import more than 2 billion dollars of food per week. Such a situation in the Middle East normally calls for increasing the efficiency for water consumption.

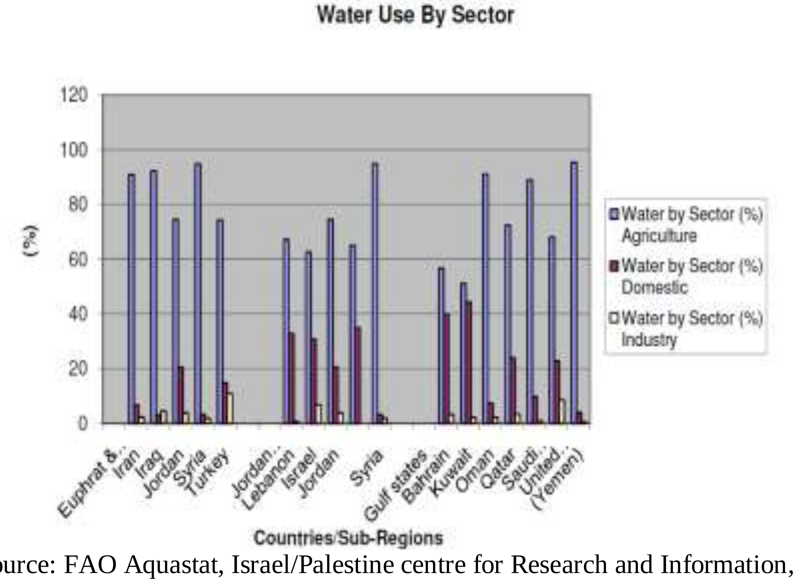
Water and sanitation.

The availability of sanitation for high income nations is up to a hundred percent, while in middle income nations it ranges from ninety percent to a hundred. The lowest accessibility to proper sanitation is in Yemen, with eighty six percent accessibility level.

Water and the economy.

The poverty rate in the region went down during the past 30 years. The private utilization of oil resources resulted in concentrated wealth and poverty. The overall region has high GDP per capita, although there is a huge gap between nations and within nations. Moreover, the population is expected to grow greatly in the Middle East over the next 40 years. Overall, the Middle East population is estimated to double. As a result, more pressure will be stressed upon natural resources.

Figure 1 Percentage of Water use per Sector



Source: FAO Aquastat, Israel/Palestine centre for Research and Information, 2011.

Water and climate change

There are several regions in the world where climate change can have a negative impact to a great extent, and one of these regions is the Middle East. The average temperature is expected to rise in addition to the inconsistency of precipitation. Climate schemes are showing different results with differences in the quantity of rainfall. Approximately, all utilized empirical models expect little differences in the level of rainfall as reported by Intergovernmental Panel on Climate Change (IPCC). Nevertheless, as a result of the water issue in the Middle East and the increase in temperature, the outcome of even minor changes in the level of rainfall will have severe consequences. The mean temperature, as stated by the utilized models, will rise between 1.2 degrees and 3 degrees Celsius in the Middle East. This will raise the evaporation rate, and consequently reduce the quantity of precipitation which will influence the recharge of aquifers. A rise in only 1 degree Celsius will probably raise agricultural water demand by 10 percent.

To be able to cope with the weather variations, countries which rely on water exhaustive agriculture in the Middle East must diversify their economies, to avoid any future economic crisis. As reported by the FAO, an estimation of 1.9 percent loss in GDP will be the result of weather variation in the Middle East, whereas a sever climate variation will result in the loss of almost 3.5 percent of the GDP. This is mainly caused by the loss of fertile lands and endangered cities situated on the coasts. Finally, as a result, food imports will rise creating a financial burden on the economies of the non-oil countries of the region.

Water Resources in Saudi Arabia

Saudi Arabia is a desert country that covers around 2 Million sq. km, with no permanent rivers or lakes and negligible rainfall level. Its renewable water resources total 95 m^3 per capita, below the 1,000 m^3 per capita benchmark commonly used to denote water scarcity. Its Population is around 28 million with a growth of 2.21 percent as shown in figure below.

Table 2 Basic Information about Saudi Arabia

BASIC STATISTICS:	2010 (1431/32)	2011 (1432/33)
Land Area : 2,000,000 Square kilometers		
Total Population (Million)	27.56	28.38
Population Growth Rate: (Saudis)	*2.21%*	*2.21%*
Life expectancy at birth (General)	73.6	73.8
Nominal Gross Domestic Product (SR Billion)	1,709.7	2,239.1
Nominal GDP per capita (SR in current prices)	62,028	78,906
Nominal GDP per capita (US$ in current prices)	16,541	21,042
Real GDP Growth	*5.1%*	*7.1%*
Inflation Rate (measured by change in the cost of living index 1999 = 100)	*5.3%*	*5.0%*
Merchandise Exports - fob (SR Billion)	941.8	1,367.6
Merchandise Imports - fob (SR Billion)	362.5	493.4
Current Account of BoP (% of GDP)	*14.6*	*26.5*
Exchange Rate (SR/US$)	3.750	3.750

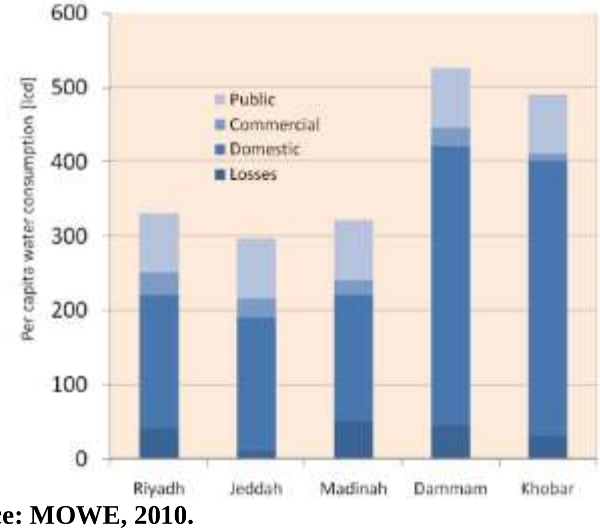
Source: Central Department of Statistics & Information, Saudi Arabian Monetary Agency.

Source: Ministry of Economy and Planning, 2012.

Figure 2 Map of Saudi Arabia

Moreover, the Per capita water consumption is high, 91 percent higher than the global average per capita consumption, (Booz C, 2012), and the demand for water is high and increasing with a growth rate of 7 percent. Total public water use in Saudi Arabia is around 9 percent and it is estimated at 2.1 billion m^3 per year in 2004. Agriculture is responsible for 88 percent and the industry for only 3 percent of the accessible water. The household water consumption is estimated around 260 litres per capita per day.

Figure 3 Per Capita Water Consumption in Major cities of Saudi Arabia



Source: MOWE, 2010.

In addition, the Unaccounted For Water (UFW) is in the range of 20 %. (UFW) is the difference between the quantity of water supplied to a city's network and the metered quantity of water used by the customers; It is divided into two components the physical

losses (leakage from pipes), and the administrative losses (illegal connections and under registration of water meters).
Finally, the price of water is high across the globe, and has been increasing over the past five years, for example, 0.75 dollars per cubic meter in the USA, 1.5 dollars per cubic meter in UK, and it is reaching 3.35 and 4.5 dollars in countries such as Columbia and Accra. However, the price of domestic water in Saudi Arabia is subsidized by the government which is almost gratis or free as per the table below (note that 1 Saudi Riyal (SR) = 0.27 US Dollars):

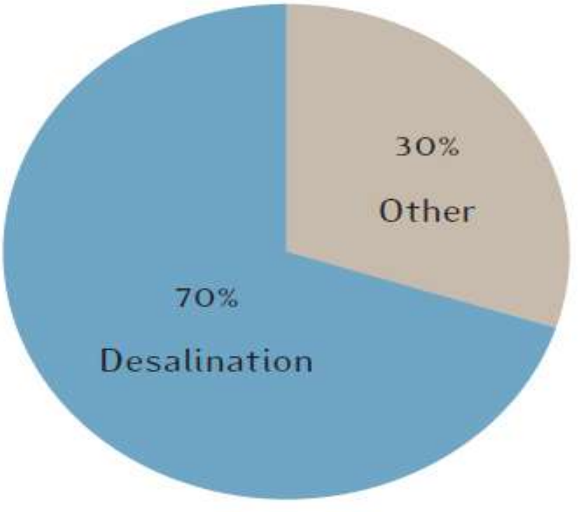
Table 3 Tariffs on Water Consumption in Riyadh (1 SR =0.27 US $)

Segment	M^3/month	Price (SR)
1	1-50	0.10
2	51-100	0.15
3	101-200	2.00
4	201-300	4.00
5	301+	6.00

Source: Al Zahrani Khodran et al, 2011.

In table 1.3 we see the tariffs on water consumption in the Capital Riyadh, which is segmented and structured according to the increase in water consumption per cubic meter, and each segment has a fixed charge. For example the last and most expensive segment, is charged for the consumption of 301 cubic meter per month or more, its charge is for 6 Saudi Riyals which is 1.62 US Dollars. Compared with the 6 US dollars per cubic meter that the government pays for the managing and pumping desalinated water to end users, it covers less than 1% of the cost of water (fewer than 0.03 US Dollars per m^3). Therefore, water is being extremely underpriced which makes demand unnaturally high and this leads to an inefficient use.
Moreover, the government cannot rely on economic instruments such as water pricing to affect the demand for water, that’s why the government has launched campaigns to encourage and motivate consumers to adopt preservative measures, such as giving away free conservation tools (faucets and showerheads) to decrease daily water consumption. The government has also launched media campaigns to encourage water conservation, focusing on moral and religious ethics, and according to a study that was carried out by the Ministry of Water and Electricity, 86 percent of Saudis are unaware that there is a shortage in water resources in the Kingdom, 82 per cent of them do not practice any conservation techniques, and finally 99 percent have no idea about the cost of desalination (Alwasat-Arabic text 2012). Moreover, dams are used to capture surface water after frequent flash floods. More than 200 dams collect an estimated 16 billion cubic feet of water annually. Some of the largest Dams are located in the Wadi Jizan, Wadi Fatima, Wadi Bisha and Najran. In addition, recycled water is another solution used by The Kingdom of Saudi Arabia, which targets the recycling of at least 40% of the water utilized for domestic uses in urban areas. Recycling plants are located in Riyadh, Jeddah, and other cities.

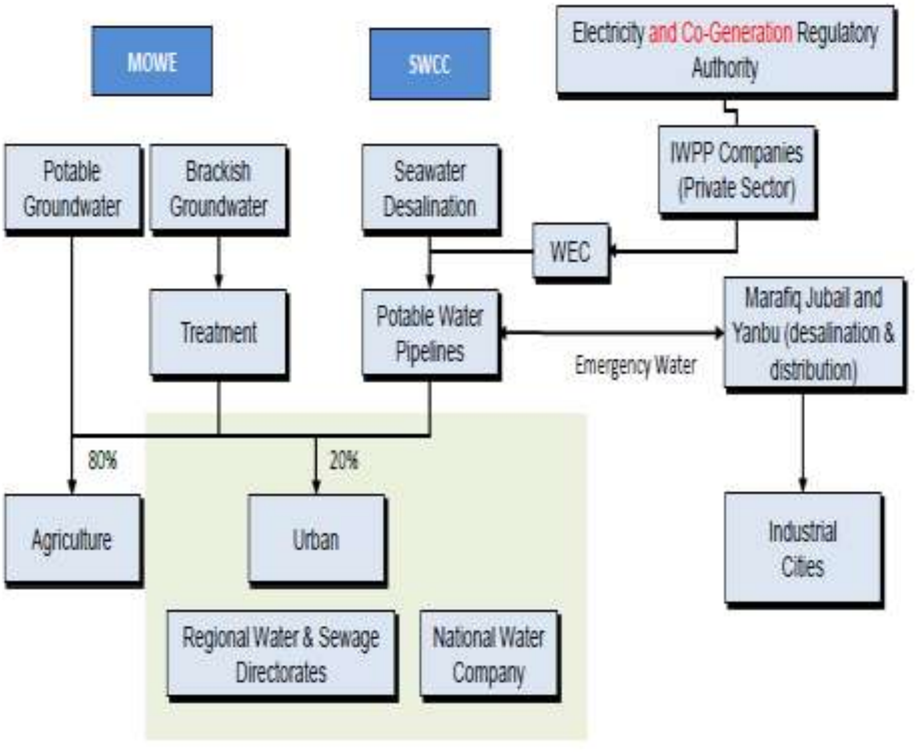
Figure 4 Resource of Water in the Average Saudi City



Source: CSIS, 2011.

However, water collected from dams and recycling plants is only used to irrigate fields, parks, and agricultural areas. In order to satisfy the needs of the increasing population the kingdom is relying on desalination plants. Desalination is a process which produces potable water from seawater. Saudi Arabia is the world's largest producer of desalinated water. The Saline Water Conversion Corporation (SWCC) operates 27 desalination stations that produce more than three million cubic meters a day of potable water. These plants provide more than 70 percent of the water used in cities, as well as, a sizeable portion of the needs of the industry.

Figure 5 Current State Water Delivery Sector in KSA



Source: MOWE, 2010.

Nevertheless, building desalination plants is costly and time consuming. Therefore, it is important that policy makers should forecast the long term water demand and set future plans in order to avoid any water crisis in the future.

Previous research

Water is the most valuable resource for the survival of human beings on earth, and the scarcity of water is an issue that might cause future tension and confrontation among the countries of the Middle East (Hamdar 2003). Therefore, many countries are becoming more aware of water scarcity including the kingdom of Saudi Arabia (KSA).

Saudi Arabia is a desert country, and has very little water natural resources such as rivers and lakes, as mentioned in the official website of KSA Embassy in Washington DC, the renewable water resources total 95 m^3 per capita, which is under the 1,000 m^3 per capita utilized to indicate the benchmark for water scarcity. Using desalination, recycling, and dams, the government has succeeded in satisfying the current water needs; however the population in the Saudi Arabia is around 28 million and is increasing annually. Water pricing is negligible since it is subsidized by the government to the extent that "The price of household water in Saudi Arabia is almost free" (Al-Zahrani. and Baig 2011); therefore, the present demand for water is very high and this might cause a threat of a severe shortage in the future.

Two main solutions were suggested to ensure the future of water resources in Saudi Arabia:

1-The adoption of policies to increase water supply.

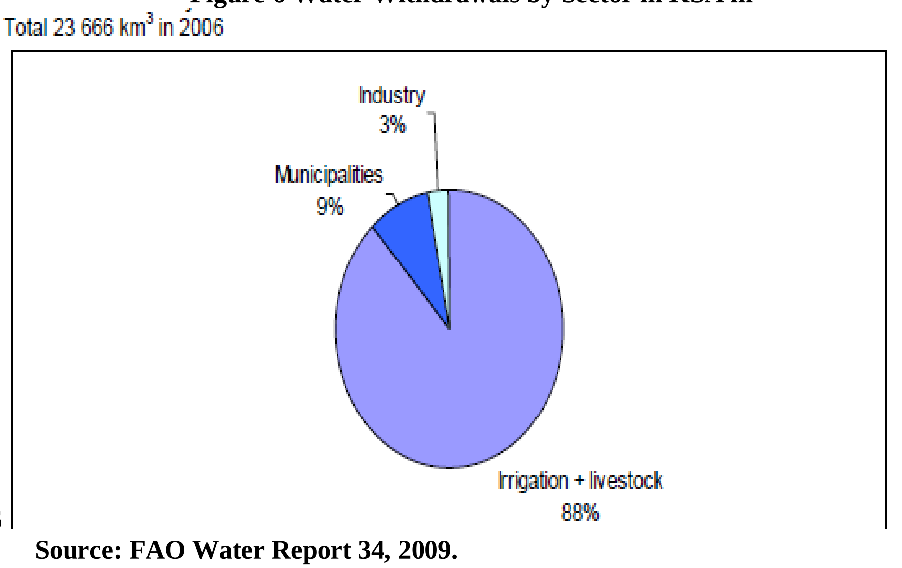
2- The balancing between supply and demand by controlling the current levels of water demand.

Research Methods

The forecast of future water demand is the key for the planning and implementation of Integrated Water Resource Management (IWRM), in such a way that it will help determine the future supply, distribution and water recycling systems. Moreover, Short-term forecasting is useful for managing current water demand; on the other hand long-term forecasting is used for planning and management. It is therefore very important that decision makers should have a reliable long term estimation of water demand, in order to prepare and implement the proper development plans, and to avoid any potential shortage in the household water supply.

Agricultural water demand accounts for more than 80% of total water demand in Saudi Arabia, since the Agricultural sector has been developed greatly due to the dedication of the government to improve agricultural production, "Nowhere in the world there is a government giving more support to farmers." Says an Irish cattleman who works in Riyadh" (Lawton 1978).Investments in dairy and poultry farms flourished as well, especially in Riyadh where milk and eggs from local farms went on sale for the first time, and therefore Fodder was planted to feed the animals resulting in more plantations.

Figure 6 Water Withdrawals by Sector in KSA in 2006



Source: FAO Water Report 34, 2009.

In 1976 and 1977, government subsidies for agriculture reached 120 million U.S Dollars and loans amounted to 140 million U.S Dollars, furthermore, in 1986 the Government founded the Saudi Arabian Agricultural Bank (SAAB), a banking organization specialized in granting financial loans to the agricultural sector. Consequently, food imports decreased while local producers were fulfilling most of their market needs. the Kingdom attained self-sufficiency in wheat, dates, table eggs, and fresh milk, it has also reached high levels of self-sufficiency in other agricultural products, such as vegetables which reached 85%, fruits 65%, red meat 36%, fish 43%, and poultry 55%, (Alzahrani 2009). This rapid development led to an increase in the contribution of agriculture to GDP from 264 million dollars in 1970 to 10.5 billion U.S dollars in 2005.

As a part of government support program, the government has provided farmers with free of charge supporting services, human resource development, pest control, veterinary and quarantine services, roads, electricity, housing, social services, seeds, saplings, herbicides, fertilizer, proper systems for irrigation, reclamation, and land distribution to boost agricultural growth.

Sufficient water supply was needed to support the agricultural sector; however, rainfall is very limited in places such as al-Hasa, and in the Qatif rainfall was practically absent. The farmers turned to aquifers and groundwater to irrigate the land; however, with time the groundwater aquifers were depleted. The total number of wells in the country is 228,927 wells, out of which 123,516 are drilled wells, 105,269 are dug wells ,and 142 artesian supplied by the upward movement of water under hydrostatic pressure in rocks or unconsolidated material beneath the earth's surface. Moreover, the authorities came up with a conservation plan to protect natural reserves of water (Al Zahrani 2009).

Regression Analysis

A log-linear regression analysis was selected as the forecast methodology, to predict the long term agricultural water demand for Saudi Arabia. The objective of this paper is to define the independent variables that affect water demand for the agricultural sector, and to define the elasticity of these variables and their effects on water demand.

The use of the price of water as a variable was considered, but the price in the majority of the cases is inelastic since water has no substitutes. Most users have no insight on the rate structure of water and on top of all of that the price is extremely subsidised in Saudi Arabia to the level that it is almost free. The price of agricultural products involved in the study was also considered. This price could be of use since the government buys the goods from the farmers at a fixed price as part of the subsidy program.

Using secondary data from the historic records of the ministry of agriculture of the kingdom of Saudi Arabia on water demand, the following regression model was created using Statistical Package for Social Sciences (SPSS).SPSS will help the experienced data analysts to perform a successful analysis or writing a meaningful report that often requires more work in acquiring, merging, and transforming data than in specifying the analysis itself. SPSS contains powerful tools for accomplishing and automating these tasks (Levesque 2007):

$$\text{Ln } Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$$

Where:

Y: is the agricultural demand for water from historical data; β_0 is the constant or the intercept of the model, β_1, β_2 and β_3 represent the elasticity of the three variables X_1, X_2, and X_3 respectively.

Before defining the variables used in this model, many variables were taken into consideration, since agriculture does not only include plantations, but also livestock; such as Cows, Sheep, Camels, Goats and poultry which reached a great number in the kingdom (In 2011 the number of Cows reached approximately 487 000, Sheep 6 563 000, Camels 220 000, Goats 1 069 000, and Poultry 528 000 000 (MOA 2012). These animals require

daily water needs for drinking cleaning and milking. However, even when considering the amount of milk that amounted to 1678 000 of tones in 2011, the effect of the livestock is still insignificant and it has no massive effect on the dependent variable (Y) which is the Demand for water in agriculture (MOA 2012).
As for the plantation, Saudi Arabia is mostly known for Cereals such as wheat, Barley, corn, and sorghum. Moreover, it is also known for vegetables mostly tomatoes, potatoes, squash, eggplant, okra, carrots, dry onions, cucumber, melons, water melons, fruits mostly dates, grapes and citrus, and finally, it is known for fodders including alfalfa. Data on these agricultural products were collected from 1985 till 2011, except for wheat (data on wheat were collected starting 2008).
Finally, the kingdom adopted a new strategy based on gradual decrease in planting wheat locally because of the scarcity of water since that one ton of wheat consumes about 2000 m^3 of water. The new policy predicted the replacement of local procurement by imports from abroad and the plan is that; by 2016 all wheat requirements will be met through imports as shown in the following table:

Table 4 Estimation of Wheat Production and Import

Year	**Local Wheat(Expected)(MT)**	Imported Wheat(Expected)(MT)
2012	1.0	2.2
2013	0.8	2.4
2014	0.6	2.7
2015	0.4	2.9
2016	0.0	3.4

Source: Grain Silos & Flour Mills Organization (Kingdom of Saudi Arabia), 2012.

Along with these data, average yearly temperature was added, knowing that there is an increase in temperature all over KSA which varies from a minimum of 0.15°C to a maximum of 0.75°C, with an average of 0.40°C every decade (Al Zawad 2008).
Utilizing the Stepwise method for log-linear regression Model using SPSS, only sorghum, alfalfa, and land were computed as the variables that were affecting the agricultural water demand the most, as for the other considered variables they were excluded for being insignificant.
The water Demand Y is therefore assumed to depend on a number of variables (Xi):
X1 is sorghum, X2 is alfalfa, and X3 is land.

Table 5 Data for Regression Analysis

Year	Water use in agriculture (MCM)	Sorghum (000 t)	Alfalfa (000 t)	Cultivated Land (000hectar)
1985	8780	43	854	946
1986	1029	43	953	947
1987	10482	117	1005	1062
1988	11181	125	644	1246
1989	12452	129	645	1327
1990	13326	171	634	1379
1991	13530	118	1038	1519
1992	14608	147	984	1571
1993	15314	175	1116	1596
1994	15317	185	1282	1596
1995	14819	207	1407	1302
1996	15317	211	1458	1173
1997	18663	209	1423	1263
1998	18054	199	1355	1130
1999	18303	205	2178	1226
2000	18000	212	1927	1120
2001	N/A	248	1969	1212
2002	N/A	240	1738	1225
2003	N/A	242	1787	1216
2004	17530	284	1769	1173
2005	18586	213	1645	1107
2006	17003	242	1581	1074

2007	15420	233	1782	1075
2008	15083	252	1963	972
2009	14747	244	2000	835
2010	14410	115	2528	807
2011	15970	117	2551	788

Source: MOA 201 and MOWE 2013.

Model results and Data Analysis

The stepwise log linear regression analysis using SPSS generated the following formula:

Ln Agricultural Demand of Water = 8.556 + 0.528 Sorghum + 0.576 Alfalfa + 0.384 Land

Table 6 Model Summary

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**					**Durbin-Watson**
					R Square Change	**F Change**	**df1**	**df2**	**Sig. F Change**	
	.913	**.834**	**.812**	**.09021**	**.084**	**11.663**	**1**	**23**	**.002**	**1.270**

Predictors: (Constant), Sorghum, Alfalfa, Land. Dependent Variable: Ln Demand

Source: SPSS.

As Shown in the results the adjusted R^2 is 0.81, which indicates that the variables used in the model explain 81% of the variation in Y.

Table 7 Anova Test

Anova [a]

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	.940	3	.313	38.494	.000[d]
Residual	.187	23	.008		
Total	1.127	26			

a. Dependent Variable: Ln Demand

d. Predictors: (Constant), Sorghum, Alfalfa, Land

Source: SPSS.

(The Anova test ensures further verification of the model appropriateness)

Table 8 Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	8.556	.154		55.724	.000	8.238	8.874
Sorghum	.002	.000	.528	4.953	.000	.001	.002
Alfalfa	.000	.000	.576	4.573	.000	.000	.000
Land	.000	.000	.384	3.415	.002	.000	.001

Source: SPSS.

The constant 8.556 derived from the formula indicates the level of water demand for agriculture when all independent variables are zero.

0.528(sorghum) indicates that a 1% change in sorghum leads to a 0.528 % change in water demand for agriculture. Sorghum and water demand are positively related, which means that an increase in sorghum leads to an increase in agricultural water demand, and a decrease in sorghum leads to the decrease of agricultural water demand.

0.576(alfalfa) indicates that a 1% change in alfalfa leads to a 0.567 % change in water demand for agriculture. Alfalfa and water demand are positively related, which also indicates that an increase in alfalfa increases water demand for agriculture and a decrease in alfalfa decreases water demand for agriculture.

0.384(Land) indicates that a 1% change in Land will lead to a 0.384 % change in water demand for agriculture. Land and water demand are positively related; indicating that an increase in land will increase the demand of water for agriculture and a decrease in land will decrease the water demand for agriculture.

Implication

The above regression model (Ln Agri. Demand of Water = 8.556 + 0.528 Sorghum + 0.576 Alfalfa + 0.384 Land) has the following implication:

1-The model reveals that water is mostly affected by the plantation of alfalfa with an elasticity of 0.567. The Government needs to ration the quantity of alfalfa produced in order to reduce the water demand for agriculture. Especially, that alfalfa is well known to be grown in all seasons rather than specific seasons like any other crops, and therefore it needs to be irrigated all year long.

2-Sorghum is the second most effective independent variable in relation to water demand for agriculture, with an elasticity of 2.528; the government could also decrease or ration the amount of sorghum produced per year to reduce the water demand for agriculture.

3-The cultivated land with an elasticity of 0.384, although it is the least effective, but nevertheless is needed if the government wants to reduce the demand for water for agriculture, and therefore the cultivated land must be reduced.

Research results and analysis

Depending on the data from 1985 to 2011that was utilized by this paper; the following log- linear regression model was created:

Ln Agricultural Demand of Water = 8.556 + 0.528 Sorghum + 0.576 Alfalfa + 0.384 Land.

The results of the regression analysis yielded a value of 0.812 for the adjusted R square. The parameter estimates (elasticity coefficients) were statistically significant (p-value less than 0.05 and t-stat larger than 2). For the sorghum, the parameter estimate (0.528) is positive, which means that the more the plantation of sorghum is increased, the more the water demand for agriculture increases to fulfil the irrigation needs for this cereal.

The parameter estimate (0.576) associated with alfalfa is also positive and is the largest of the three elasticity coefficients. As the number of alfalfa plantations increases, water demand for agriculture increases. Finally, the parameter estimate (0.384) for the yearly irrigated agricultural Land is positive; however, it is the least effective, which means that an increase in the cultivated land increases water demand, but at a lower rate of that of alfalfa or sorghum.

Using the above equation a future water demand for agriculture could be forecasted, and plans could be made accordingly. For example, the water demand for agriculture in 2011 was 15970 (MCM), if the amount of alfalfa production is reduced by 1%, the demand for water in agriculture decreases by 0.576%; therefore, the quantity of water decreases by almost 92 Million cubic meters.

According to the 9th development plan of the ministry of economic and planning, the average annual growth rate of land (Area) was - 4.9%, and the annual average growth rate of fodder(mostly alfalfa) was 3.2% from 2004 till 2008. As mentioned in the table below:

Taking the same measurement method and using the available data retrieved from the MOA, the average annual growth rate of sorghum is -2.8 %, knowing that the amount of sorghum in 2004 was 284 (000 tons) and in 2008, it became 252 (000 tons), which is a total of -11.3 % decrease, divided by 4, it amounts to -2.8% as a yearly average.

Assuming Ceteris Paribus (all else is fixed), we could use these growth rates to project the future amount of sorghum, alfalfa, and land.

Years	2011	2020	2030
Alfalfa (000 tonnes)	2551	3282	4641
Sorghum (000 tonnes)	117	94	69
Land (000 hectares)	788	537	318

And therefore, forecast the future demand for agriculture using the regression equation:

Ln Agri. Demand of Water = 8.556 + 0.528 Sorghum + 0.576 Alfalfa + 0.384 Land

Years	2011	2020	2030
Forecasted Demand of water for agriculture (MCM)	15970	2155	2840

In 2020 the forecasted demand for water is to decrease until it reaches 2155 (MCM), which is about an 87% decrease in water demand. Unfortunately, this rate will decrease in 2030 due the increase in alfalfa and due to its high correlation with water demand.

Thus, it could be concluded that by the year 2020, a total of 87% of Water will be reduced if the land and sorghum amounts will keep decreasing at the same rate. But, the alfalfa growth of 3.2% per year will be the cause for the increase; in the demand for irrigation water in 2030.In other words; alfalfa production must be reduced or rationed before it drains the water resources of Saudi Arabia, since it requires irrigation all year long.

Summary and concluding remarks

This paper was based on a log-linear regression analysis method to forecast long term water demand for the most water demanding sector in Saudi Arabia. Historical data were analyzed and the data revealed that a predictive model based on alfalfa, sorghum, and Land could forecast the water demand for agricultural trends.

The used model of the paper was effective in the estimation of long term agricultural water demand, using the average annual growth rates of alfalfa, sorghum, and land from 2004 till 2008 to project the future value of the agricultural water demand. Moreover, this model was used to analyze the impact of each of the independent variables on the demand for water for agriculture based on the consideration of the elasticity of the variables utilized.

With the government subsidy programs for water, it seems that the only realistic option for the reduction of the use of agricultural water is a good policy for the control of plantations, whether by decreasing the amount of production of related agricultural activities or simply by improving the irrigation systems to decrease the excess of water which is wasted by evaporation, and finally, creating more awareness programs for farmers to enlighten them about the proper use of water.

The arid and desert climate of The Kingdom of Saudi Arabia (KSA) is ranked one of the driest countries in the world. Based on the data and information presented in this paper, there is a need to manage the demand of water resources by changing the pattern of water demand for the most water consuming sector ,which is the agricultural sector, using over 80% of the total water supply in Saudi Arabia.

The increase in water supply through desalination cannot be the permanent solution, since the cost of desalination is very high .A considerable amount of water is being wasted due to inefficient use and irrational practices by the general public. The users in Saudi Arabia take water for granted, since they consider it as a free commodity because the kingdom provides subsidies for the price of water. All stakeholders including the policy makers, planners and residents need to re-think the importance of this precious resource, its efficient use and wise consumption.

The best suggested option is the implementation of the concept of Integrated Water Resource Management (IWRM) which holds significant potential. IWRM must be viewed as a managerial approach aimed at meeting the demand of water through the application of necessary and efficient measures and incentives to achieve fair and effective utilization of water. The role of extension education is of prime importance. Without creating awareness among the users and educating the general public on the importance of this resource, all conservation measures adopted would be limited in affecting the level of water demand.

The methodology used to support this study was the log-linear regression analysis method using the three most effective independent variables: Alfalfa production, Sorghum production, and the cultivation of land.

The equation obtained from this method allows the estimation of agricultural demand assuming no change occurs. Finally, the results obtained are extremely significant and relevant to the topic.

This paper indicates that the water crisis in Saudi Arabia should be a top priority for the government, since it affects the country on all levels. Historical data were analyzed to create a predictive model, this model showed that agricultural water was mostly affected by three major factors which are the alfalfa, sorghum production, and cultivated land. The analysis also showed the specific effect of each one of those factors on the agricultural water demand using the concept of elasticity.

Finally, water demand is estimated for 2020 and 2030, using the average annual growth rates of alfalfa, sorghum, and land from 2004 till 2008(Ceteris Paribus).

Thus, solutions are suggested such as to ration the plantation of alfalfa, and to create awareness programs at the same time for an effective planning of water use in the kingdom of Saudi Arabia.

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