Camels Don't Fly, Deserts Don't Bloom:

an Assessment of Saudi Arabia's Experiment in Desert Agriculture

by

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Severe arid conditions constrained agricultural production and population size in the Arabian Peninsula over the millennia (except around oases and in parts of Yemen). An abrupt change in Saudi Arabia started in the 1980s to make the desert bloom. This study examines whether or not the Saudi experiment in desert irrigation has been worthwhile in terms of cost and benefit. It concludes that the project was a waste of money and water on a grand scale.

The study will start by describing a brief history of the project. It will be followed by an estimate of the scheme's cost in terms of: a) money and, b) water. It will end with an analysis of the feasibility of Saudi quest for food self-sufficiency. The data are from Saudi Government and other official sources.

1. History of agricultural development in Saudi Arabia since the 1960s

Table 1 Saudi population, land and water use and production of agricultural products for 1961, 1973, 1980 and 1985-2000

Years	Pop-ulation-millions	Cereals		Vegetables		Fruits		Alfalfa		Meat excl. fish (000 tons)	Milk (000 tonne-s)	Water use (billion m3)	Total land (000 ha.)
		Land (000 ha.)	Tonn-es (000)	Land (000 ha.)	Tonn-es (000)	Land (000 ha.)	Tonn-es (000)	Land (000 ha.)	Tonn-es (000)				
1961	4.2	NA	361	NA	216	NA	186	NA	360	38	97	N/A	343 a
1973	6.6	201	113	18	399	38	355	29	344	81	217	N/A	373 a
1980	9.6	455	267	53	756	72	470	29	388	74	349	7.472	609
1985	12.2	634	2,191	93	1,443	75	686	145	2,134	303	414	11.607	946
1986	12.9	643	2,463	87	1,281	78	714	139	2,036	380	432	11.71	947
1987	13.6	718	2,934	99	1,911	82	781	163	2,405	396	450	13.053	1,062
1988	14.2	898	3,695	98	1,953	82	817	168	2,395	423	451	14.814	1,246
1989	14.9	968	3,950	105	1,894	88	848	166	2,294	400	475	15.682	1,327
1990	15.4	978	4,138	109	1,900	91	804	201	2,106	404	516	16.513	1,379
1991	15.8	1,090	4,575	106	1,904	96	834	227	2,514	410	520	18,384	1,519
1992	16.1	1,125	4,704	124	2,073	103	899	219	2,425	428	548	18.949	1,571
1993	16.4	1,133	5,044	125	2,181	113	951	226	2,435	470	587	19.642	1,596
1994	16.7	1,071	4,861	134	2,289	118	988	273	2,784	511	633	20.165	1,596
1995	17.1	708	2,671	159	2,692	130	1,052	305	3,069	544	698	19.088	1,302
1996	17.6	566	1,934	156	2,631	139	1,090	313	3,157	552	749	18.718	1,173
1997	18.2	659	2,340	162	2,599	146	1,150	297	2,929	608	816	18.663*	1,263
1998	18.9	624	2,204	120	2,166	147	1,149	239	3,200	552	883	18.054*	1,130 b
1999	19.6	690	2,474	91	1,875	191	1,153	234	3,606	577	937	18.303*	1,226 b
2000	20.4	620	2,168	91	1,926	193	1,189	217	3,262	643	1,039	N/A	1,120 b

Sources: - Population data and (a) are from FAO Statistical Database.
        - Data marked (b) are from Saudi Statistical Yearbook (SSY), 2001: p.511.
        - All other data are from Ministry of Agriculture and Water (MAW), as presented by A. S. Altukhais, Vice Minister, 2002: tables 4, 5 and 6.
        * MAW Preliminary estimates.

The dramatic change during the ten years or so between the early 1980s and the early 1990s resulted from the sudden and large inflow of revenues from crude oil exports, following the quadrupling of oil prices in October 1973 Middle East war.[1] Since then profound changes in the Saudi economy and people's living standards took place.

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[1] In 1970, crude oil revenues (in nominal terms) were SR7.122 billions (US$1.58 billions at the then official rate of exchange of SR4.5 to US$1). In 1974, they jumped thirteen folds to SR94.19 billions (US$26.5 billions at SR3.55/US$1). In 1979, they doubled to SR189.295 billions (US$56.3 billions at SR3.3608/US$1). They peaked in 1981 to SR329 billions (US$94 billions at SR3.5/US$1). By 1986, they declined to SR42.464 billions (US$11.3 billions). Since 1987, they averaged SR117 billions (US$31 billions). In 2001, they were SR184 billions (US$49 billions [Saudi Arabian Monetary Agency (SAMA) Annual Report, 2002: p.388]

Table 1 shows that as late as 1961, the irrigated surface was limited to 343,000 hectares with a population of 4.2 millions. Twelve years later, by 1973, the irrigated surface was still 373,000 hectares. The emphasis, however, shifted from producing cereals to vegetables, fruits, meat and milk. Cereals production dropped from 361,000 tonnes in 1961 to 113,000 tonnes in 1973, of which wheat was merely 64,000 tonnes. Population had grown during the same period to 6.6 millions.

Between 1973 and 1992, increased wealth and improved living conditions led to increasing the Saudi population by about 250%, to 16.4 millions, many being expatriate workers. 1992 is chosen as a demarcation line here because it was the year that: A) followed the 1991 Gulf war with its heavy burden on Saudi treasury.[2] B) The year in which wheat production reached its highest level (Table 2). C) The growth of government subsidies to wheat production was reversed. D) Barley growing was emphasized, albeit for only two years (Table 2).

Wheat growing became the prime target of government support in the early part of the 1980s. Until 1981 the proportion of wheat to total cereal production was around 50%. The ratio jumped in 1981 to 63.7% and in 1982 to 85.3% (Table 2). This high percentage was maintained for ten years. During this period, wheat production steadily increased to reach a record 4,124,000 tonnes in 1992,[3] well in excess of the self-sufficiency requirement of the country's 16.1 million population. Also, well beyond the storage capacity of the government's Grain Silos and Flour Mills Organization (GSFMO) of 2.38 million tonnes (Saudi Ministry of Planning (MOP), 2003: p.140).[4]

In 1992 the government began to emphasize barley growing. Within one year, in 1993, production jumped by 340%, to 1.421 million tonnes from 417,000 tonnes in 1992.

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[2] According to the Saudi Minister of the Interior (Arab News Newspaper, Riyadh, September 27, 2002), the 1991 Gulf war had cost Saudi Arabia US$80 billion.

[3] To put the magnitude of this development in perspective, Egypt in 1993, with a population of 59.3 million, had an irrigated surface, evolved over the centuries, of 3 million hectares and wheat production of 4.8 million tons (FAO Statistical Database).

[4] GSFMO is a government agency established in 1972 to develop agro-industries and achieve self-sufficiency in wheat with six-month reserve stock as a strategic objective. In 1978, GSFMO capacity was 40,000 tons. It grew to 2.38 million tons in 1989 where it stood in 2000/2001 (MOP, 2003: p.140, 146).

One year later, in 1994, barley production peaked to 2.01 billion tonnes (Table 2). The number of farmers who sold their barley to GSFMO increased commensurately. In 1992, the number was 4,015 farmers. In 1993, it jumped to 11,804 farmers and in 1994, to a maximum of 12,637 farmers (SSY, 2001: p.538).

To achieve this enormous growth, the all-cereals producing surface was increased by a phenomenal 924,000 hectares (1.125 million hectares in 1992 – 201,000 hectares in 1973), or by 560%. The overall irrigated surface of all crops expanded by 1.198 million hectares, from 373,000 hectares in 1973 to 1.571 million hectares in 1992, or by 421%. The irrigated surface expanded further in 1993 to 1.596 million hectares. An arid Saudi Arabia was turned into the world's sixth largest wheat exporting country (Richards and Waterbury, 1998: p.160 and Altukhais, 2002: 12). During the same period (1973 to 1992), the surface of the "other" agricultural irrigated area increased impressively as well, by 274,000 hectares (1.198 million hectares – 924,000 hectares), or 259%.[5] Production of the other crops increased sharply, vegetables; by 520% (to 2.073 million tonnes from 399,000 tonnes), fruits; by 253% (to 0.899 million tonnes from 355,000 tonnes) and alfalfa; by 705% (to 2.425 million tons from 344,000 tonnes). Also, red meat and poultry increased by 528% (to 428,000 tonnes from 81,000 tonnes) and milk by 253% (to 548,000 tonnes from 217,000 tonnes). [6]

Starting 1993, however, financial pressures forced the Saudi government into a policy reversal. Combined with the cost of the 1991 Gulf War and persistent budget deficits since the early 1980s,[7] caused the government a severe shortage of liquidity.[8] In

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[5] 446,000 hectares in 1992 (1.571 million hectares for all crops – 1.125 million hectares for cereals)/ 172,000 hectares in 1973 (373,000 hectares for all crops – 201,000 hectares for cereals) = 259%.

[6] Flowers and tulips, grown in greenhouses at Astra Farms in Tabuk in northwest Arabia were air freighted to, among others, Holland.

[7] Between 1984 and 1990 aggregate budget deficits was SR366.791 billions, or about US$100 billions. In 1991, the deficit was SR104.491 billions, or about US$28 billions. It dropped in 1992 to SR67.160 billions, or about US$18 billions at the SR3.75/US$1 exchange rate (MOP, 2003: p.195).

[8] Saudi government liquidity became so short that ministries and other official agencies delayed for many months, sometimes for 2 years or more, paying on the due dates the equivalent of many billions of US$ to several thousands suppliers, contractors and farmers for goods supplied or work performed. The over dues were eventually paid, without interest, in the form of medium term government bonds. To gain desperately needed liquidity, most bondholders discounted their bonds at the country's commercial banks, at attractive

1992, subsidies to primarily wheat growing were reduced by 12%, from a peak of SR6 billions in 1991 (US$1.6 billions) to SR5.28 billions (US$1.4 billions). In August 1993, it was announced that the government would not buy wheat in 1994 from the six main commercial producers, while imposing quota restrictions on purchases from smaller commercial farmers (Europa, 2003: p.957). In 1995, the subsidies dropped by 50% from 1994 [SR2.536 billions from SR5 billions (Table 2)]. The slide continued till the subsidies became about SR0.94 billions (US$249 millions) in 2000 (Table 2).

Within 4 years, by 1996, the all-cereal growing surface dropped by a dramatic 559,000 hectares (1.125 million hectares in 1992 – 566,000 hectares in 1996), or by 50%. Wheat production dropped even more steeply, by 70% (1.2 million tonnes in 1996/ 4,124 million tonnes in 1992). By 2000, however, wheat production recovered to a level sufficient for the country's domestic consumption, 1.787 million tonnes (Table 2).

Barley production's fall was similarly dramatic. Within one year, 40% of the 2.01 billion tonnes produced in 1994 was cut, to 794,000 tonnes in 1995. The number of farmers delivering barley to GSFMO dropped from 12,637 farmers in 1994 to 2,126 farmers in 1995 (SSY, 2001: p.538). Since then, barley growing continued its sliding trend. In 1999 production was only 192,000 tonnes, with the number of barley growers who sold to GSFMO dropping to 368 farmers (MOP, 2003: p.538). In 2000, production became 118,000 tonnes (Table 2). Meanwhile, barley imports in 2001 were 3.25 million tonnes. The cost was SR1.55 billion, or SR477 per tonne, or US$127 per tonne (SSY, 2001: p.446), considerably less costly than locally produced barley (Section 2.E below).

Vegetables production declined marginally, from 2.181 million tonnes in 1993 to 1.926 million tonnes in 2000. On the other hand, increases between 1993 and 2000 took

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discount rates to the banks. The balances outstanding of such bonds as of the end of 2002 were: 1) SR235.7 billions, or US$62.9 billions, in the from of "special government bonds… primarily to contractors." 2) SR37 billions, or US$9.9 billions, as "farmers certificates," (SAMBA, February 2003: p. 16). The affected parties were foreign companies as well. Boeing, for example, stopped deliveries of the new 777 aircrafts to government owned Saudi Airlines for months. Delivery of the first new aircraft had to wait until the Saudi government borrowed about US$5 billion from foreign banks to fulfill the Boeing contract.

place in fruits production; from 951,000 tonnes to 1.189 million tonnes, in red meat and poultry; from 470,000 tonnes to 643,000 tonnes and, in milk; from 587,000 tonnes to 1.039 billion tonnes. In December 2003, the government imposed a five-year ban on the allocation of public land for farming (Arab News Newspaper, December 12, 2003).

Despite the drop in cereal production, agricultural water consumption remained strong. The drop in irrigation water use was less proportional to the drop in cereals production or the size of the irrigated surface. Between 1993 and 1999, while the overall irrigated surface declined by 23% (1.126 million hectares in 1999/ 1.596 million hectares in 1993), irrigation water was reduced by only 9% (18.303 billion m3 in 1999/ 19.642 billion m3 in 1993). The water saved from growing less wheat and barley was used to increase production and exports of alfalfa plus live animals and animal products, which require considerably more water to produce. For the five years 1990 to 1994, average water use was 12,225 m3 per hectare (93.653 billion m3/ 7.661 million hectares). For the following five years 1995 to 1999 water use increased to an average of 15,232 m3 per hectare (92.826 billion m3/ 6.094 million hectares). That the reversal in policy on subsidies to cereals was designed to conserve water cannot be supported by the facts.

1.A. Saudi exports of virtual water

Between 1993 and 1999, Alfalfa production increased by almost 1.2 million tonnes, from 2.435 million tonnes in 1993 to 3.606 million tonnes in 1999. Such a volume was beyond local needs. Alfalfa was exported to neighboring markets. In 2000, the government banned alfalfa exports. So, production declined. The drop within one year was 344,000 tonnes (3.606 million tonnes in 1999 – 3.262 million tonnes in 2000). The drop in alfalfa crop happened while production of red meat and poultry during 2000 increased to 643,000 tonnes from 577,000 tonnes in 1999, and of milk to 1.039 million tonnes in 2000 from 937,000 tonnes in 1999, an indication that earlier increases in alfalfa production was for export purposes, not local meat growing. Alfalfa requires six times as much water to grow as wheat (Altukhais, 2002: p.12). Generally, one thousand tons of water (1,000 cubic meters) is needed to produce a ton of wheat (Allan, IW&I, 2001:p.39).

The water saved from abandoning the growing of 2.613 million tonnes of wheat and barley between 1993 and 1999 [9] was used up to grow 1.2 million tonnes of alfalfa.

Additionally, Saudi Arabia exports two categories of foodstuffs that require substantial water to produce. The first is live animals and animal products. The average between 1997 and 2001 was about US$191 millions for each of the five years.[10] Saudi Arabia's exports of live animals and meat products could be estimated at 127,333 tonnes for each of the subject years.[11] This quantity represented about 20% of the country's meat production in 2000 (127,333 tonnes / 643,000 tonnes). It also represented 74% of the increase in meat production between 1993 and 2000.[12] Meat production requires huge volumes of water. Generally, it needs about 16,000 cubic meters to produce a ton of meat (Allan, IW&I, 2001: p.39). Saudi meat exports are synonymous with shipping away the country's finite water resources. 127,333 tonnes of annual meat exports is like shipping away 2.04 billion m3 of water annually (127,333 tonnes* 16,000 m3 of water per tonne).

The second category of food exports with large water consumption is agricultural produce. Between 1997 and 2001, Saudi Arabia exported a total of SR2.095 billions (SSY, 2001: p.447), or an average of SR419 millions per annum, or about US$112 millions. Assuming that the per ton water requirements of these exports is similar to the average water requirements of all crops in the country, Saudi water exports in this category would be about 2,000 m3 per tonne (18.303 billion m3 in aggregate irrigation water use in 1999 (Table 1)/ 9,108,000 tonnes of crops produced in 1999 (Table 1) = 2,010 m3 per tonne). Assuming further that the average export price of agricultural products was US$500 per tonne, Saudi annual exports would have been 224,000 tonnes

[9] 2.613 million tonnes of wheat and barley = (3.43 million tonnes of wheat in 1993 + 1.421 million tonnes of barley in 1993 = 4.851 million tonnes) – (2.046 million tonnes of wheat in 1999 + 192,000 tonnes of barley in 1999 = 2.238 million tones (Table 2 below)).

[10] Total exports of SR3.587 billions (SSY, 2001: p.447)/ SR3.75 per US$1 = US$957 millions/ 5 years = US$191.4 millions per year.

[11] Given that this category includes live animals, red meat, meat products and poultry, an average export price of US$1,500 per ton will be assumed. Saudi exports of US$191 million per annum between 1977 and 2001 would translate to 127,333 tons (US$191 millions/ US$1,500 per ton).

[12] 127,333 tons/ (643,000 tons in 2000 – 470,000 tons in 1993)= 74%.

(US$112 millions/ US$500 per tonne), thus requiring 448 million m3 of water annually (224,000 tonnes* 2,000 m3 per tonne).

In terms of water, between 1997 and 2001 the above two export categories reduced Saudi water reserves by about 2.488 billion m3 annually (2.04 billion m3 + 0.448 billion m3). If the water embedded in alfalfa exports until it was stopped in 2000 were added, the water lost to agricultural exports could possibly double. Cumulatively, the estimated volume of Saudi water exports during this five-year period in the form of meat, fruits and vegetables was some 12.44 billion m3 (2.488 billions* 5 years). To put this figure in perspective, the country's population of 23 million requires about 2.1 billion m3 per annum for drinking and household uses.[13] And, while the water used to grow foodstuffs is lost forever, the majority of household water (about 75%) is returned as sewage to be treated for reuse. If all sewage water is treated, the net volume of domestic water use could be estimated at 525 million m3 (2.1 billion m3* 25%), or about 21% of the water embedded in annual food exports (525,000 million m3/ 2.488 billion m3).

Meanwhile, strong population growth continued unabated. It grew by 40%, from 16.4 millions in 1993 to 23 millions in 2001 (SAMBA, February 2002: p.1) of whom about 6 millions were foreign workers and families. Rapid population growth and higher meat content in Saudi diet plus meat exports led to raising red meat and poultry production from 470,000 tonnes in 1993 to 643,000 tonnes in 2000, and milk production from 587,000 tonnes in 1993 to 1.039 million tonnes in 2000.

This short history of Saudi agriculture shows that Saudi Arabia's foray into cereals production is a case of unsustainable development. Within one decade, a desert was made into a major world producer of wheat. Four years later, a precipitous decline of 70% followed. The retrenchment, however, did not reduce irrigation water use commensurately. The government did not ban the exports of alfalfa, meat, fruits and

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[13] At an average of 250 liters per day (Altukhais, 2002: p.13), annual per capita drinking and household uses would be 91.25 m3, or 2.1 billion m3 for a population of 23 million in 2002 (91.25 m3 * 23 millions = 2.099 billion m3 per annum).

vegetables. This experiment simply showed that a combination of money and water could make even a desert bloom, until either the money or the water runs out.

Financial pressures already forced the Saudi government into a policy reversal on subsidizing wheat and barley beyond the country's domestic needs. More threatening in the future, however, is the inevitable consequence of continuing the extraction of the country's non-renewable reserves at the present levels. Accurate reserves estimates of groundwater are at best challenging. It is certain, however, that regardless of how vast Saudi non-renewable water reserves might be, extraction will sooner or later, deplete the aquifers; thus, forcing the abandonment of desert agriculture altogether. The date is a function of the extracted volume (Section 5 below). Whenever this happens the balance of government and private sector investments in agriculture will be written off.

Irrespective of estimates, signs of declining availability and deteriorating quality of Saudi groundwater have already become serious. Natural springs which discharge many aquifers have dried up in most parts of the Western, Central and Eastern regions along with seawater intrusion in areas of the East Coast. Also, as a result of poor quality sanitary and drainage systems and the unmonitored use of inorganic fertilizers and pesticides the quality of water in most aquifers has become brackish (Saudi Water Net). The New York Times (January 23, 2003) reported the Minister of the newly formed Ministry of Water as saying: "I remember flowing springs when I was a boy in the Eastern Province. Now all of these have dried up and you have to dig." A local wheat farmer in Qassim was reported as saying: "I've had to lower my pumps 100 meters" - 328 feet – "in the past 10 years." This farmer's "4,000-foot-deep wells bring up water that is increasingly mineral-laden," the article continued. Qassim is Saudi Arabia's major wheat producing are in the Central Province.[14] The following two sections will address the cost of Saudi agriculture in general and cereals production in particular in terms of money and water. It will also examine the possible motives behind this fateful undertaking.

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[14] In 2000 the crop area in the Central province was 485,242 hectares (255,865 hectares for Riyadh + 229,377 hectares for Qassim) out of a total of 1.12 million hectares, or 43% (SSY, 2001: p.511).

2. The financial cost of Saudi agriculture

The rapid development in Saudi irrigation between the early 1980s and 1994 was prompted and promoted by government subsidies to farming in general and to growing wheat and, later barley, in particular. As these subsidies were instituted, then increased and declined, crop production increased and declined. The financial cost of growing agricultural products at home over and above the cost of importing a similar volume of foodstuffs from abroad represents the sum total of four components. The first is the cost of the direct subsidies that the Saudi government pays to farmers. The second is the cost of the indirect government subsidies that benefit farmers. The third is the annual economic cost of operating government infrastructure projects that benefit the agricultural sector. The fourth is the cost of production incurred by private sector farmers.

2.A. Direct government subsidies

Table 2 lists Saudi wheat and barley production between 1973 and 2001 as well as the quantities of wheat purchased and the prices paid to wheat growers by between 1979 and 2000 (amounts between 1980 and 1983 are unavailable). It also shows the amounts of the subsidies paid by GSFMO for local wheat and barley. These subsidies are imputed. They represent the difference between the import prices that could have been paid (on FOB basis), had the wheat and barley been imported, and the prices that GSFMO paid to local farmers. The subsidies reflect the extra cost of home grow cereals.

Table 2 The effect of subsidies on growing wheat and barley (1973-2000)

Year	Total irrigated land (000 ha.)	Of which: all-cereal land (000 ha.)	All-cereal grown (000 tonnes)	Of which: 1) barley (000 tonnes)*	Of which: 2) wheat (000 tonnes)*	% Wheat to all cereals	Wheat bought by GSFMO (000 tonnes)**	Total amount paid for wheat by GSFMO (SR millions)**	Per ton Amount paid for wheat by GSFMO (US$)	GSFMO imputed subsidy for wheat and barley (SR Million)**
1973	373*	201	113	11	64	56.6%				
1974	375*	414	300	15	153	51				
1975	375*	347	289	17	132	45.7				
1976	390*	432	283	12	93	32.9				
1977	390*	393	295	14	125	42.4				
1978	400*	406	302	15	120	39.7				
1979	500*	434	350	13	150	42.9	18	SR61	$1,009	45
1980	609	455	267	5	142	53.2	NA	NA	NA	NA
1981	575	276	295	6	187	63.4	NA	NA	NA	NA
1982	597	264	489	5	417	85.3	NA	NA	NA	NA
1983	731	320	876	2	817	93.3	NA	NA	NA	NA
1984	783	450	1,447	2	1,402	96.9	1,347	4,248	841	2,775
1985	946	634	2,191	4	2,135	97.4	2,030	4,060	548	2,004
1986	947	643	2,463	121	2,290	93	2,132	4,260	533	3,239
1987	1,062	718	2,934	154	2,649	90.3	2,419	4,835	533	4,037
1988	1,254	898	3,695	285	3,276	88.7	3,128	5,979	506	4,829
1989	1,326	968	3,950	335	3,452	87.4	3,208	5,936	493	4,256
1990	1,379	978	4,138	372	3,580	86.5	3,584	6,697	498	5,087
1991	1,520	1,090	4,575	407	4,035	88.2	3,861	7,230	499	6,005
1992	1,571	1,125	4,704	417	4,124	87.7	3,460	6,632	511	5,280
1993	1,596	1,133	5,044	1,421	3,430	68	2,980	5,696	510	5,269
1994	1,596	1,071	4,861	2,010	2,646	54.4	2,557	4,870	508	5,001
1995	1,302	708	2,671	794	1,648	61.7	1,648	3,296	533	2,536
1996	1,173	566	1,934	500	1,200	62.1	1,200	1,800	400	853
1997	1,263	659	2,340	315	1,795	76.7	1,795	2,692	400	1,005
1998	1,130***	624	2,204	250	1,734	78.7	1,734	2,602	400	1,253
1999	1,226***	690	2,474	192	2,046	82.7	1,736	2,604	400	1,052
2000	1,120***	620	2,168	118	1,787	82.4	1,750	2,625	400	935
Total 1984-2000			53,793 (a)	7,697	43,229		40,569	76,062		55,416

Sources: * FAO Statistical Database.
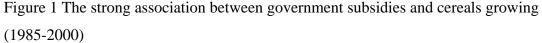
      ** Saudi Ministry of Planning (2003).

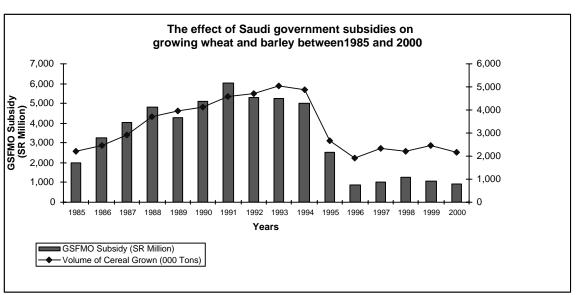   *** Saudi Statistical Yearbook (2002).

    All other data are from Saudi Ministry of Agriculture and Water as outlined by its Vice Minister, A. S. Altukhais (2002).

    (a) Represents all cereals including sorghum, millet and corn.

Table 2 shows that during the 16 years between 1984 and 2000, the Saudi Government paid SR76.062 billion were paid to purchase 40.569 million tonnes of domestic wheat, an average of SR1,875 per ton, or US$502 per tonne.[15] The international market price for wheat during the same period averaged about US$120 per tonne.[16] Of the purchase price, the direct subsidy portion over and above the cost of imports totaled SR55.416 billions, or US$14.8 billions.[17] The average annual subsidy for each of the subject 16 years over and above imports' cost was US$925 million (US$14.8 billions/ 16 years). The per tonne average was US$307 [US$14.8 billions/ (40.569 million tonnes of wheat + 7.697 million tonnes of barley)]. Since 1992, the subsidies declined. The 2000 amount was SR935 millions, or US$249 millions (SR935 millions/ SR3.75 per US$1). The per-tonne subsidy was SR491 [SR935 millions/ (1.787 million tonnes of wheat + 118,000 tonnes of barley)], or US$131 per tonne (SR491/ SR3.75 per US$1).

Figure 1 The strong association between government subsidies and cereals growing (1985-2000)

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[15] SR4.248 billions in 1984/ SR3.58 per US$1 (exchange rate in 1984) + SR4.06 billions in 1985/ SR3.65 per US$1 (exchange rate in 1985) + SR67.754 billions for 1986-2000/ 3.75 per US$1 (exchange rate since 1986) = US$20.366 billions/ 40.569 million tonnes = US$502 per tonne.

[16] The average price is for Louisiana wheat. Arkansas average price was about US$114.

[17] SR2.775 billions in 1984/ SR3.58 per US$1 + SR2.004 billions in 1985/ SR3.65 per US$1 + SR50.637 billions for 1986-2000/ SR3.75 per US$1 = US$14.8 billions.

During the same period (1984 – 2000), direct subsidies from the government owned Agricultural Bank to the agriculture sector totaled SR7.1 billions, or US$1.9 billions [18] (MOP, 2003: p.220). These were introduced in 1973 to assist farmers to purchase mainly engines and pumps for groundwater extraction and also general farm machinery.[19] Additionally, direct subsidies to poultry feed between 1985 (the year of inception of the program) and 2000, totaled SR3.9 billions, or US$1.04 billions [20] (MOP, 2003: P.220). The total of these two subsidies was US$2.94 billions, or US$183.8 millions for each of the subject years.

In 2000, government subsidies to general agriculture was SR266.4 millions and to poultry feed, SR383.9, thus totaling SR650.3 millions, or US$173.4 millions (SR650.3 millions / SR3.75 per US$1).

Total direct subsidies to the agricultural sector between 1984 and 2000 would be US$17.7 billions (US$14.8 millions +US$1.9 millions + US$1.04 millions).[21] The average annual amount of subsidies between 1984 and 2000 would be US$1.1 billions (US$17.7/ 16 years).[22]

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[18] (SR1.449 billions in 1984/ SR3.58 per US$1) + (SR1.080 billions/ SR3.65 per US$1) + (SR4.584 billions/ SR3.75 per US$1) = US$1.9 billions.

[19] The subsidy program granted 45% of the price of farm machinery, 50% of the price of fertilizers, 50% of the price animal feed concentrate, 30% of poultry plus dairy farms (20% if financed by the Agricultural Bank) and 100% of transportation cost of 200 or more daily cattle (SAMA, 1976 Annual Report: p.58).

[20] (SR267.4 millions/ SR3.65 per US$1) + (SR3.641 billions/ SR3.75 per US$1) = US$1.04 billions.

[21] This is in addition to the cost of concessionary terms that the government owned Agricultural Bank provides on its long-term loans for well drilling and casing, irrigation equipment, farm-machinery and pumps, as well as the short-term working capital loans to help farmers purchase fuel, fertilizers, seeds, insecticides and pay labor's wages. These loans are effectively interest free. Total loans disbursed since the bank's inception in 1965 and 2000 reached SR32.5 billions (SAMA, 2001: p.225), or US$8.7 billions.

[22] Additionally the imputed value of the land given away by the government under the 1968 Regulation for Fallow Land Distribution and specifically used for crop growing should be added. By 1999, the distributed land reached 3 million hectares (SAMA, 2001: p. 229).

2.B. Indirect government subsidies

In addition to the direct subsidies, the annual imputed value of a range of indirect subsidies to input factors of production need to be added, such as, electricity [23] plus the fuel to operate farm machinery, transportation equipment and pumps. Irrigation water in Saudi Arabia is mostly extracted through the use of mechanical energy produced by pumps driven by electricity from diesel generators. It is estimated that the energy required for pumping 1 m3 of water from wells range between 0.4 Kilowatt-hour (Kwh) and 0.8 Kwh (W. Abderrahman, 2001: p.247), depending on well's depths. As such, the electricity needed to lift 18.303 billion m3 of irrigation water in 1999 would have ranged between 7.3 million Megawatt-hours (Mwh) (18.303 billion m3* 0.4 Kwh) and 14.6 million Mwh (18.303 billin m3* 0.8 Kwh), or an average of 10.95 million Mwh [7.3 million Mwh + 14.6 million Mwh)/ 2]. During 1999, industrial and private electricity consumption was 111 million Mwh (SSY, 2001: p.352). Thus, in terms of energy, the cost of the 1999 Saudi irrigation water supply could be estimated at about 10% of total Saudi electricity consumption cost (10.95 million Mwh/ 111 million Mwh).

2.C. Estimate of government capital investment in agricultural infrastructure projects and their annual economic cost of operations

The economic cost of operations, depreciation, and maintenance of government infrastructure projects that benefited agricultural development should be added, including an opportunity cost of government capital investment in its best alternative use. Such projects include, for example, irrigation canals, land reclamation, drainage schemes, rural roads and dam construction. The 5-year development plan between 1975 and 1979 allocated SR39 billions to the development of agriculture as well as water resources, of which SR4.685 billions, or US$1.3 billions (SR4.685 billions/ SR3.5 average exchange rate of the period) were for agricultural development programs (SAMA, 1976: p.58). The

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[23] Between 1984 and 2000, government subsidies to electric companies were SR11.695 billions (MOP, 2003: p.220), or US$3.17 billions (SR3.05 billions/ SR3.58 per US$1 + SR1.75 billions/ SR3.65 per US$1 + SR6.8949 billions/ SR3.75 per US$1 = US$3.17 billions).

5-year plan between 1980 and 1984 allocated SR72 billions (SAMA, 1981: p.65), of which SR7.975 billions, or about US$2.3 billions (SR7.975 billions/ SR3.48 average exchange rate for the period) were for agriculture (Europa, 2002: p.909). Between 1984 and 2000, based on calculations from data in Ministry of Planning's "Achievements of the Development Plans, 2003," it may be estimated that government capital investment in agriculture and related projects totalled about SR21.7 billions, or about US$5.8 billions.[24] Total government capital investment in agricultural projects between 1975 and 2000 would, thus, be estimated at around US$9.4 billions (US$1.3 billions + US$2.3 billions + US$5.8 billions). Assuming annual operating overhead of 5% of capital investment, depreciation charges of 4% (composite useful life of 25 years) and opportunity cost of capital of 5%, the cost of operating government's infrastructure projects that benefited the agricultural sector in 2000 would be guesstimated at US$1.3 billions (US$9.4 billions* 14%). This represents US$ 1,161 per hectare annually [US$1.3 billions/ 1.120 million hectares (table 1)], or US$152 per tonne of all crops (US$1.3 billions/ 8.545 million tonnes in 2000). If the aggregate rates for opportunity capital cost, operations and depreciation were assumed to be 20% instead of 14%, the annual operating overhead becomes US$1.88 billions (US$9.4* 20%), instead of US$1.3 billions.

These subsidies and investments were made during a period of persistent and large budget deficits. Between 1984 and 2000, the total deficit reached SR762 billions, or US$203 billions (MOP, 2003: p.195). Consequently, government debt in 2001 reached about SR630 billions, or about US$168 billions (SR630 billions/ SR3.75 exchange rate), representing 99% of the 2001 estimated Saudi GDP (SAMBA, February, 2002: p.1).

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[24] Total government gross fixed capital formation between 1984 and 2000 at 1994 constant prices was SR597 billions (MOP, 2003: p.211). To estimate the proportion of this amount that was allocated to agricultural projects, it is assumed here that the proportion was equal to the difference in the contribution that the agricultural sector made into Saudi GDP, between the average of a few years before 1984 and the average of the period between 1984 and 2000. This was 3.635% (6.735% being the average contribution of agriculture, forestry and fishing into GDP between 1984 and 2000 – 3.1%, the average contribution of the same sector to GDP in 1969, 1974 and 1979 = 3.635%). Thus, 3.635%* SR597 billions = SR 21.7 billions. Over the subject 16 years, this was equivalent to US$5.8 billions [(SR74.01 billions of capital formation in 1984/ SR3.58 per US$1 exchange rate in 1984) + SR50.31 billions of capital formation in 1985/ SR3.65 per US$1 exchange rate in 1985) + SR473 billions of capital formation between 1986 and 2000/ SR3.75 per US$1 exchange rate since 1986)], or some US$363 million per annum (US$5.8 billions/16 years). This guesstimate is consistent with the actual investments of the previous ten years of US$3.6 billions (US$1.3 billions + US$2.3 billions), or US$360 millions per annum (US$3.6 billions/ 10 years).

2.D. Estimate of private sector's capital investment in agriculture and the annual economic cost of production

Finally, the cost of producing agricultural crops needs to be estimated. Between 1984 and 2000, it may be estimated that private sector capital investment in agricultural and related projects totaled about SR31.6 billions, or about US$8.5 billions.[25]

Assuming a depreciation rate of fixed assets of 5% (at a composite useful life of 20 years), operational expenses of 10% of investment [26] and opportunity cost of capital of 5%, private sector cost of production in 2000 would be US$1.7 billions (US$8.5 billions * 20%), or US$1,518 per hectare [US$1.7 billions/ 1.12 million hectares (Table 1)]. Should the assumed rates be different, cost of production would change correspondingly. This does not include pre 1984 investments, due to unavailability of data.

2.E. Total financial cost of the Saudi agricultural venture

Table 3 summarizes the estimated financial cost of Saudi agriculture to the nation between 1984 and 2000. In terms of capital spending, the government and the private sector are estimated to have invested about US$17.9 billions (US$9.4 billions + US$8.5 billions). This investment increased the irrigated surface from 609,000 hectares in 1980 to 1.12 million hectares in 2000, for US$35,029 per hectare [US$17.9 billions/ (1.12 million hectares – 609,000 hectares)].

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[25] Total private sector gross fixed capital formation between 1984 and 2000, at 1994 constant prices, was SR869 billions (MOP, 2003: p. 211). To estimate the proportion of this amount that was allocated to agricultural projects, it is assumed here that the proportion was equal to the difference in the contribution that the agricultural sector made into Saudi GDP, between the average of a few years before 1984 and the average of the period between 1984 and 2000. This was 3.635% (6.735%, the average contribution of agriculture, forestry and fishing to GDP between 1984 and 2000 – 3.1%, the average contribution of the same sector to GDP during 1969, 1974 and 1979 = 3.635%). Thus, SR869 billions* 3.635% = SR31.6 billions. This was equivalent to US$8.5 billions for the subject 16 years [(SR65.1 billions of capital formation in 1984/ SR3.58 per US$1 exchange rate in 1984) + SR54.3 billions of capital formation in 1985/ SR3.65 per US$1 exchange rate in 1985) + SR750 billions of capital formation between 1986 and 2000/ SR3.75 per US$1 exchange rate since 1986)].

[26] These include paying for, among others; seeds, tillage, planting, chemical control, fertilizing, harvesting, packaging, crop transportation and land rent.

In terms of annual operating expenses, this may be estimated at US$4.109 billions for each of the 16 years involved at 1994 constant prices (Table 3). This makes the per-tonne cost of all-agriculture produce in 2000 some US$481 [US$4.109 billions/ 8.545 million tonnes (Table 1)] and the total of operating expenses between 1984 and 2000 about US$65.7 billions (US$4.109* 16 years). Thus, the estimated total financial outlay of this venture becomes US$83.6 billions (US$17.9 billions+ US$65.7 billions).

Additionally, the agricultural sector benefited from three subsidies, un-quantified here; namely, a) subsidized electricity and fuel prices, b) concessionary borrowing terms from the Saudi Agricultural Bank on US$8.7 billions [Section (2.A) above] and, c) government land given away under the 1968 Regulation for Fallow Land distribution (Section 2.C). Also, the discussion did not address: d) the cost of abandoning 476,000 hectares, or 30% of the country's irrigated surface (from 1.596 million hectares in 1994 to 1.12 million hectares in 2000), which resulted from reducing government subsidies since 1994. If these elements were accounted for the cost of the venture becomes greater.

Table 3 Saudi capital investments in agriculture, annual operating expenses and government subsidies (1984-2000) (US$ billions)

	Capital Investment (1)	Annual Operating expenses (2)	Average annual govt. direct subsidies to cereals production (1984–2000) (3)	Average annual direct govt. subsidies for general agricultural purposes (1984-2000) (4)	Total direct govt. subsidies (1984-2000) (5)=(3)+(4)	Total annual operating expenses + govt. subsidies (6)=(2)+(5)
Government	9.4	1.3	0.925	0.184	1.109	2.409
Private sector	8.5	1.7				1.7
Total	17.9	3	0.925	0.184	1.109	4.109

The return from the Saudi agricultural scheme between 1984 and 2000 is summarized in Table 4. It shows the country's total production of foodstuffs during the period and an estimate of their value based on the guesstimated value of similar imports for the duration.

Table 4 Saudi foodstuffs production (1984-2000) and their estimated value

	Cereals	Vegetables	Fruits	Red meat	Poultry	Milk	Total
Production (million tonnes) (1)	53.793	34.031	15.763	2.459	5.386	10.522	
Estimated Per-tonne average Value 1984-2000 (US$) (2)	150*	300	600	2,000	750	250	
Product value (US$ billions)	8.1	10.2	9.5	4.9	4	2.6	39.3

Sources: (1) Table 1, for the period between 1985 and 2000 + Altukhais (2002: tables 4 and 5) for the 1984 production year.
     (2) Personal estimates.
     * About US$120 per tonne + some US$30 in freight and insurance

To summarize, between about 1984 and 2000, Saudi agriculture spent US$17.9 billions in capital investment plus US$65.7 billions in production costs (US$4.109 billions* 16 years), not including the four elements mentioned in (2.E) above, for a total of US$83.6 billions. This enabled local production of foodstuffs that could have been imported for less than US$40 billions. Additionally, the venture's water cost was a mammoth 300 billion m3 of the nation's mainly non-renewable water endowment. This issue will be examined in Section 3.

2.F. Water depletion premium

Valuation of depletable resources, such as water, requires the inclusion of an opportunity cost component for depletion, or depletion premium. The premium represents the present value of the estimated future cost increases that will be associated with water extraction finite reserves in addition to the normal market value of water (its marginal extraction cost).

In order to include depletion premium in the economic cost of Saudi irrigation water the present value of the estimated increases in future extraction costs resulting from deeper wells and/or from degradation in water quality should be added. These estimates are at best conjectural. They typically suffer from a number of inherent uncertainties such as the present knowledge about the size and useful life of the reserves and the level of future prices for water. Due to lack of reliable data, no attempt to quantify this cost element will be made.

3. The cost of Saudi agriculture in terms of water

The cost of Saudi agricultural policies in terms of water consumption has been gigantic. Saudi Ministry of Agriculture and Water (MAW) data in Table 5 show the rapid development in the country's agricultural surface between 1980 and 1994 and the accompanying increase in the volume of irrigation water. It also shows the contrast during 1994 to 2000 between the steep decline in the size of the irrigated surface and the relatively insignificant drop in water consumption. Given that rainfall is scant and perennial rivers and lakes non-existent, Saudi agriculture is practically entirely dependant on irrigation from ground water reserves.

Table 5 Saudi irrigation's water use (1980-1999)

Year	Cultivated area (hectare)	Water use (million m3)		
		From partially renewable Sources	From renewable sources	Total water use
1980	437,177	3,199	4,273	7,472
1981	575,473	4,537	4,513	9,050
1982	596,941	4,846	4,508	9,354
1983	731,264	5,080	5,208	10,288
1984	782,694	7,092	3,341	10,433
1985	946,359	8,503	3,104	11,607
1986	947,383	8,652	3,058	11,710
1987	1,061,777	9,269	3,784	13,053
1988	1,254,060	10,437	4,377	14,814
1989	1,326,257	11,110	4,572	15,682
1990	1,379,154	11,230	5,283	16,513
1991	1,519,755	13,279	5,105	18,384
1992	1,570,817	13,966	4,983	18,949
1993	1,596,404	14,330	5,312	19,642
1994	1,595,546	14,224	5,941	20,165
1995	1,302,363	12,539	6,549	19,088
1996	1,173,312	12,074	6,644	18,718
Total 1980-1996	18,796,737	164,367	80,555	244,922
1997*	1,263,218			18,663
1998*	1,130,493**			18,054
1999*	1,226,289**			18,303
2000	1,119,769**			
Total 1980-1999	22,416,736			299,942

Source: Ministry of agriculture and Water as presented by its Vice Minister, A.S.
Altukhais (2002: table 6).
    * Preliminary estimates.
    ** From Saudi Statistical Yearbook, 2001: p.511.

From Table 5, total irrigation groundwater extracted between 1980 and 1999 was estimated to be 299.942 billion m3.[27] The average per hectare water use between 1980 and 1999 may be estimated at 14,083 m3 per hectare (299.942 billion m3 in total water use between 1980 and 1999/ 21,296,967 hectares in total cultivated area during the same period). About one third of the water, 80.555 billion m3, was classified as having been supplied from "renewable" sources (80.565 billion m3 in total use between 1980 and 1996/ 244.922 billion m3 in total water use during the same period = 32.9%). The remaining two thirds, 164,367 billion m3, was classified as having been extracted from

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[27] This is Equivalent to 5.5 years of water flow from the Nile River into Egypt (300 billion m3/ 55 million m3 per annum flow).

"partially renewable" aquifers. It should be noted from Ministry of Planning estimates that the volume of non-renewable water consumption is much greater than that reported by Ministry of Agriculture and Water (Table 6).

It is difficult to guesstimate how much, if any, of this huge volume of water was actually renewed or replenished. Classifying water sources as "renewable" does not mean replenishment. It does not even mean equilibrium in aquifers' water balance between sources and uses. It merely describes a physical characteristic of the land, being able to absorb and store rainwater if and when water becomes available. Actually, it may be contended that during the past twenty years, over extraction from Saudi "renewable" water sources has turned the balance in the aquifers into negative. This is because water extraction has been greater than rainfall. While rainwater after evaporation is estimated at less than 2 billion m3 per annum,[28] the volume of extracted water had increased from 4.3 billion m3 in 1980 to 6.6 billions m3 in 1996. If over-extraction continues it will cause water levels to deepen, pressure to weaken and extractable volume to dwindle. These will increase salinity and the amounts of quality-degrading minerals in the water. Recent evidence shows that such problems have already been manifesting themselves increasingly in most parts of the country (Section 1).
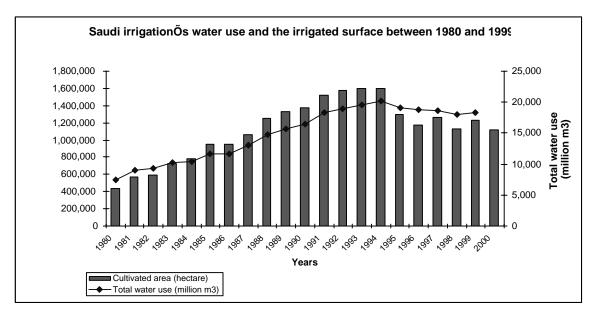
As for the "partially renewable" aquifers, extraction will lead to deterioration in their water quality and gradual depletion. It is estimated that between 1982 and 1997 the number of wells increased from 26,000 to 86,000 (W. Abderrahman, 2001: pp.249, 250). Water extraction from "partially renewable" sources climbed from 3.2 billion m3 in 1980 to 14.3 billion m3 in 1993, then dropped to 12 billion m3 in 1996, for a total extraction during the period of 164 billion m3 (Table 5). MAW's notion that the geological formations of Saudi "partially renewable" aquifers might possibly be allowing the

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[28] Aside of the South Western mountainous area, rainfall is scant. Evaporation is high. It is thought that 20% of the rain evaporates immediately and a further 50% through water runoff in seasonal streams (Saudi Water Net). Flash floods are frequent. In order to avert flooding, replenish aquifers and utilize the collected water in irrigation and households the government constructed by 2000 a total of 197 dams with aggregate storage capacity of 810 million m3 (SSY, 2001: p.536).

replenishment of water in these aquifers from unidentified underground sources (A. Altukhais, 2002: p.3) is at best conjectural.

As discussed in Section 1, the drop in irrigation water use was much less proportional to the drop in cereals production or the size of the irrigated surface. Between 1994 and 1999, while the overall irrigated surface declined by 23% (1.126 million hectares in 1999/ 1.596 million hectares in 1994), water used in irrigation was reduced by only 9% (18.303 billion m3 in 1999/ 19.642 billion m3 in 1993). Figure 2 illustrates.

Figure 2 The excessive use of irrigation water between 1994 and 1999 as compared with 1980 and 1993

Saudi irrigationÕs water use and the irrigated surface between 1980 and 1999

4. The challenge of Saudi data

Conflicting estimates between Saudi Ministry of Planning (MOP) and Ministry of Agriculture and water cast doubt on the accuracy of official Saudi data. Quoted by W. Abbderrahman (2001: table 2), MOP estimates that overall Saudi water supply from surface and renewable sources was 2.1 billion m3 in 1990, and 2.14 billion m3 in 1996. These volumes contrast with MAW's estimates of irrigation alone, 5.283-billion m3 in 1990 and 6,644 billion m3 in 1996 (Table 5).

Also, Ministry of Planning reported that overall water supply from "non-renewable" sources was 24.489 billion m3 in 1990 and 15.376 billion m3 in 1997. These compare with Ministry of Agriculture and Water supply figures of 11.23 billion m3 in 1990 and 12.074 billion m3 in 1996 for irrigation purposes. It is curious to note that the planning ministry uses the word "non-renewable" to signify what the agricultural ministry describes as "partially renewable" groundwater sources.[29]

Table 6 summarizes the divergence in the sources of water estimates between the two ministries. It shows that between 1990 and 1997 the divergence between the two ministries narrowed. However, the divergence in the allocation between renewable and non-renewable sources remained wide.

Table 6 Saudi Renewable and non-renewable water estimates, according to Ministry of Agriculture and Water and Ministry of Planning for 1990, 1996 & 1997 (billion m3)

	1990 MAW	1990 MOP	1996 MAW	1997 MOP
Renewable water (1)	5.283	2.1	6.644	2.14
Non-renewable (2)	11.23	24.489	12.074	15.376
Total (3)	16.513	26.589	18.718	17.516
(1) / (3)	32%	7.9%	35.5%	12.2%

Source: A.S. Altukhais (2002: table 6) and W. Abderrahman (2001: table 2).

The divergence between the two ministries is also reflected in the volume of water used by the agricultural sector. While, according to MAW, irrigation used 7.472 billion m3 in 1980, 16.513 billion m3 in 1990 and 18.3 billion m3 in 1999, MOP reports 1.85 billion m3 in 1980, 25.589 billion m3 in 1990 and 11.2 billion m3 in 2000. Table 7 summarizes.

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[29] Saudi Water Net reports that in 2000, "non-renewable groundwater" supply was estimated at 12.3 billion m3 while "surface and renewable" water supply was 1.8 billion m3.

Table 7 Agriculture use of water according to Ministry of Agriculture and Water and Ministry of Planning (1980–2000) in billion m3

	1980	1990	1999	2000
MAW	7.472	16.513	18.303	N/A
MOP	1.85	25.589	N/A	11.2

Source: A.S. Altukhais (2002: table 6) and W. Abderrahman (2001: table 1)

5. Saudi water availability

Groundwater represents the major water source in Saudi Arabia. Rainfall is scant. There are two types of groundwater, renewable and non-renewable. The country's severe arid conditions cause surface and renewable groundwater to be very limited. Estimating their volumes accurately is difficult. According to Ministry of Agriculture and Water, renewable water aquifers are encountered in about one third of the surface of Saudi Arabia, known as the "Arab Shield" (Altukhais, 2001: p.3). Table 5 attributes to renewable water sources one third of total irrigation water use (80.565 billion m3/ 244.922 billion m3). Much of Saudi renewable groundwater is thought to be in the Southeastern region. Water from this source may be accessed through wells ranging in depths between a few meters and 100 meters. As discussed above, "Renewable" does not necessarily mean full water replenishment of the extracted water. It could even be argued that the water balance in these aquifers has been negative since 1980, probably earlier. It may be predicted that unless water extraction is reduced to the level of water sources, these aquifers will eventually run out of water.

Non-renewable aquifers represent the major source of water in Saudi Arabia. It is thought that they were formed 600 million years ago (Altukhais, 2002: p.3). Water may be found at depths ranging from 100 meters to 500 meters, sometimes up to 2,500 meters. Due to the unavailability of mechanical means and money they remained largely undisturbed until the early 1980s when exploitation started in earnest.

There are 27 non-renewable aquifers in Saudi Arabia. Reserves are estimated to be about 500 billion m3 (Saudi Water Net). About 50% is thought to be in five locations.

Table 8 Groundwater reserves estimates in the five major aquifers (billion m3)

Aquifer	Proven	Probable	Possible
Saq	65	100	200
Wajid	30	50	100
Minjur & Dhruma	18	35	85
Wasia	120	180	290
Umm ErRadhuma	16	40	75
Total	249	405	750

Source: Saudi Water Net

The first deep water well was drilled in 1937 by ARAMCO in the Eastern province. In 1956, the Minjur aquifer was discovered as a result of drilling the Shumaisy well in downtown Riyadh. The Ministry of Agriculture and Water started surveying groundwater resources in the early 1960s. The effort was intensified in the 1970s using advanced tools and methods. The estimated volumes of these surveys were alarmingly low to scientists, researchers and others. In the early 1980s, two "detailed" MAW studies concluded that considerably more groundwater reserves existed than was previously estimated (Altukhais, 2002: p.11). This was the prerequisite needed to embark upon an ambitious project to make the desert bloom.

Using MOP's 1997 estimate of Saudi overall water uses, 500 billion m3 of non-renewable water reserves could be depleted within 33 years [500 billion m3/ 15.376 billion m3 per annum (Table 6)] from the date of the estimate. Using MAW's data will extend the expected period to 38 years.[30] These projections assume that:

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[30] Since MAW's data cover irrigation water use only, water for household and industrial uses drawn from non-renewable sources should be added for proper comparison. This is estimated at 1 billion m3 per annum (2 billion m3 for the two non-irrigation uses – 1 billion m3 in desalinated and treated wastewater). The useful life estimate under MAW's data becomes 38 years [500 billion m3/ (12.074 billion m3 per annum (Table 5) + 1 billion m3) = 38.2 years].

a) Reserves estimates are current. If not, water consumption figures in Table 5 between the actual date of the survey and the present time need to be deducted. This could reduce the 500-billion m3 reserves by as much as one third, to 336 billion m3 (500 billion m3 in proven reserves – 164 billion m3 utilized between 1980 and 1999 (Table 5). 336 billion m3 could be depleted within 22 years, using MOP's 1997 estimate [336 billion m3/ 15.376 billion m3 annually (Table 6)] and 26 years, using MAW's 1996 estimate [336 billion m3/ (12.074 billion m3 annually (Table 6) + 1 billion m3)]. Clearly, if the volume of water reserves is greater than 500 billions, or if new reserves will be discovered, the useful life of the aquifers becomes longer.

Table 9 Estimate of the expected remaining useful life of Saudi non-renewable aquifers

Estimated volume of water reserves in non-renewable aquifers (billion m3)	Years of useful life using MAW estimates	Years of useful life using MOP estimates
500	500 / 13.074* = 38	500 / 15.376 = 33
336	336 / 13.074* = 26	336 / 15.376 = 22

* 12.074 billion m3 in 1996 irrigation plus 1 billion m3 for domestic and industrial uses.

Table 9 shows that the expected useful life of non-renewable Saudi aquifers may range between 22 years and 38 years, provided that:

b) Water reserves are extractable in their entirety. If not, the aquifers' useful life becomes shorter.

c) Aggregate agricultural water use will remain constant. Unless its growth is disallowed, agriculture is more likely to require greater volumes of water for two reasons: 1) population growth will increase the demand for food. 2) Increased affluence will introduce more meat products into Saudi diet, which requires considerably more water to grow (Allan, IW&I, 2001: p.39).

There are two other sources of water supply in Saudi Arabia. Treated wastewater, used mainly for irrigation, and desalinated water for drinking, household and industrial uses. They are relatively small in volume. In 2000 the former was around 0.2 billion m3. The latter was approximately 1 billion m3. Desalinated water meets about 50% of household water demand with the remaining 1 billion m3 or so per annum being extracted from wells.

Table 10 Estimates of 1999 Saudi water uses and sources (billion m3)

	Groundwater	Rain	Treated wastewater	Desalinated water	Total
Agriculture	18*	0.5**	0.2		18.7
Domestic	1			1	2
Industry	0.35			0.1	0.45
Total	19.35	0.5	0.2	1.1	21.15

* Ministry of Agriculture and Water (Table 7 above).
** A 25% guesstimate of rainfall of 2 billion m3 per annum.

Total water available and used may be estimated at about 21 billion m3 of which groundwater sources provided 19.35 billions m3, or 91.5% of total water supply.

5.A. Alternative guesstimate of Saudi water availability

How much water might be left in Saudi aquifers? It may be guesstimated that irrigation water extraction exhausted thus far about two thirds of the country's known non-renewable aquifers. "A technique first published in 1956 by M. King Hubbert… observed that in any large region, unrestrained extraction of a finite resource rises along a bell-shaped curve that peaks when about half the resource is gone (Colin J. Campbell and Jean H. Laherrere, March 1998)." While Hubbert's theory was developed in connection with fossil fuel production and reserves, Hubbert (1949: p.107) found that "a growth

curve of the utilization of water power, should rise in a manner similar to those of the fossil fuels."[31]

Given that: 1) Saudi water extraction has been unrestrained since the start of the country's foray into agricultural production since the early 1980s [the decline in cereal production that started in 1994 was compensated by almost a corresponding increase in the production of other crops (Table 1)] and, 2) the volume of water extraction from "partially renewable sources," according to MAW, described as "non-renewable" by MOP, reached a peak of 14 billion m3 in 1994 (Table 5), it might be presumed that 1993/1994 signifies the midpoint in the volume of Saudi non-renewable water reserves that prevailed around 1980. Up to that time water extraction was rather small- 3 billion m3 in 1980, (Table 5) less so in prior years.[32] It follows that, according to Hubbert's theory, the volume of Saudi non-renewable water was likely to be around 300 billion m3 [140 billion m3 in total extractions between 1980 and 1994 (Table 5)* 2= 280 billions)], not 500 billion m3.

Unless new aquifers will be discovered and/or the volume of extraction changed the remaining reserves in 2001 might be estimated at around 90 billion m3 [300 billion m3 – (164 billion m3 extracted between 1980 and 1996 (Table 5) + estimated extraction of about 48 billion m3 between 1997 and 2000].[33] At this level, the remaining useful life of the reserves would be about 7 years according to MAW estimate (90 billion m3/ 13.074 billion m3) and about 6 years, according to MOP estimate [90 billion m3/ 15.376 billion m3 (Table 9)].

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[31] Hubbert's contribution has been acclaimed in scientific and industrial circles. At a conference to honor the 100th anniversary of his birth, Hubbert was described as "the single greatest influence on the development of the quantitative study of groundwater hydrology."

[32] Total cultivated land in 1980 was 609,000 hectares. In 1973, it was 373,000 hectares (Table1), thus requiring less water.

[33] Average of 12 billion m3 in each of the four years, as prevailed in 1996, given that the cultivated surface during this period remained equal to that of 1996 of about 1.2 million hectares.

6. Saudi water requirement

Like other countries, there are three main water uses in Saudi Arabia. The first is to grow foodstuffs. Typically, this is by far the greatest use everywhere. "An individual needs each year at least 1,000 cubic meters of water, either naturally occurring in soil profiles, or transported to the profiles by irrigation systems, to raise the food needs of that individual" (Allan, 2001: p.6). The composition of diet determines the volume of water embedded in food. While it requires one thousand tons of water (1,000 cubic meters) to produce a ton of wheat, it requires about 16,000 cubic meters of water to produce a tonne of meat (Allan, IW&I, 2001: p.39). Therefore, the more meat a diet contains the more water embedded in food is consumed. Saudi Arabia's 23 million-population in 2002 would need an estimated 23 billion m3 of water per annum in the form of foodstuffs (23 million population* 1,000 m3 per person).

The second water use is for household purposes, cooking, cleaning and sanitation. This generally ranges between 50 m3 and 100 m3 annually, less in rural communities. The Saudi average is 250 liters per day (Altukhais, 2002: p.13). It makes the annual per capita drinking and household water use some 91.25 m3, or 2.1 billion m3 in 2002 (91.25 m3* 23 millions). Per capita drinking water averages merely 1 m3 per annum.

The third water use is industrial. Its volume is rather modest, estimated in 2000 at around 450 million m3 (Altukhais, 2002: p.5).

Total Saudi water requirements could be estimated at about 25.55 billion m3 (23 billion m3 for irrigation + 2.1 billion m3 for drinking and households + 0.45 billion m3 for industry). Of this volume, 90% is used in agriculture (23 billion m3/ 25.55 billion m3) and the remaining 10% in other uses. Total water use at the present time is about 21.15 billion m3 (Table 10). The deficiency would be about 4.4 billion m3, or 17.2% of the country's water needs. As Saudi population grows, water demand and associated deficits are expected to grow proportionately. The water deficit will have to be met through the importation of food, or virtual water.

7. Saudi quest for food independence

Saudi population growth is strong. With a rate of about 3.84% between 1980 and 2000 (from 9.6 millions to 20.4 millions), it has been among the highest in the world.[34] It is forecast to reach 31 millions in 2010 (Statistical Abstract of the United States: 2000: p.823) and over 40 millions in 2025 (Altukhais, 2002: p.4). Given such a high rate of growth and regardless of how large Saudi water reserves might be, food independence is an impossible task to sustain on the long run. This is because Saudi groundwater reserves are mainly non-renewable. Their finite nature makes it only a matter of time before irrigation exhausts their recoverable contents.

Despite using mammoth volumes of water over the past two decades and spending huge amounts of money, Saudi food sufficiency remains illusive. In 2001, Saudi Arabia imported SR18 billions in foodstuffs, or US$4.8 billions [SR18 billions (SSY, 2001: p.448)/ 3.75 exchange rate). During the 5 years ending in 2001, food imports totaled US$24.6 billions, or an average of US$4.9 billion annually (SSY, 2001: p.448). Hoekstra and Hung (2003: p.42), estimate that between 1995 and 2000 Saudi Arabia's imports of foodstuffs were equivalent to gross virtual water imports of 11.313 billion m3 per annum. Although major achievements in food sufficiency have been made, the ratio is expected to retract. The current volume of water extraction from the country's non-renewable aquifers could not be sustained for a long time in the future.

A population of 23 millions means that their annual consumption of water 1,000 m3 per person (Allan, 2001: p.6). Given the agricultural ministry's estimates that in 1999 the volume of water used in irrigation was about 18 billion m3 (Table 1) the ratio of locally produced foodstuffs to the country's total needs would be around 78% (18 billion m3/ 23 billion m3). The proportion becomes 49% (11.2 billion m3 (table 4.6)/ 23 billion m3) if the data of the ministry of planning were used. The Hoekstra and Hung estimate is more compatible with Ministry of planning than Ministry of Agriculture and Water data.

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[34] The combined Saudi population growth of nationals and foreign workers slowed to 3.49% between 1985 and 2000 (from 12.2 millions to 20.4 millions, respectively) and further down to 2.84% between 1990 and 2000 (from 15.4 millions to 20.4 millions, respectively).

In 2010, Saudi water consumption embedded in foodstuffs could be estimated to reach 31 billion m3 (31 million population* 1,000 m3 per person). Assuming that the volume of irrigation water remains unchanged, the proportion of food produced domestically to total food requirements, according to MAW, would drop to 58% (18 billion m3/ 31 billion m3). The proportion becomes 36% (11.2 billion m3/ 31 billion m3), using MOP data.

In 2025, Saudi water consumption embedded in foodstuffs could be estimated to reach 40 billion m3 (40 million population* 1,000 m3 per person). Assuming that the volume of irrigation water remains unchanged from its 18 billion m3 in 1999, the proportion of food produced domestically to total food requirements, according to MAW, would drop further to 45% (18 billion m3/ 40 billion m3). The proportion would be 28% (11.2 billion m3/ 40 billion m3), using MOP data.

Table 11 Estimates of Saudi domestic production of foodstuffs as a proportion of the country's total requirements

Year	Population (millions)	MAW data estimates (%)	MOP data estimates (%)
2002	23	78	49
2010	31	58	36
2025	40	45	28

Will there be sufficient groundwater by 2010, or 2025 to maintain irrigation at the 2000 level of 1.12 million hectares? The answer is doubtful. An additional 25 years of water extraction at the MOP rate of 15.376 billion m3 per annum (Table 6) would deplete about 385 billion m3 (15.376 billions* 25 years). At the MAW estimate of 12.074 billion m3 per annum, depletion would be 302 billion m3 (12.074 billions* 25 years). These are dangerously high utilization rates relative to the estimated proven reserves of 500 billion m3, let alone 336 billion m3 (Sections 5 and 5.A).

8. Possible motives behind Saudi foray into desert agriculture

Why was it that the Saudi Government chose the course of expensive agricultural development for an arid country despite its persistent and large budget deficits during the 1980s and 1990s? Is it: A) food independence. B) Settlement of the Bedouins, or C) enriching the ruling elite? It was probably a combination of all three, but with a special emphasis on (C).

8.A Food independence

This notion has a nationalistic appeal. It conveys a message of control over Saudi Arabia's own political and economic destiny. The strategy might have been prompted by threats in the US media to withhold food supplies as leverage against unacceptable oil export and pricing policies, following the 1973 oil boycott and quadrupling of prices. However, the claim cannot be supported by the facts. There are 2 reasons here:

The first reason is that self-sufficiency in foodstuffs provides neither political nor economic independence. A review of Saudi balance of trade shows the country's heavy reliance on the developed world. Indeed, no country could possibly attain comparative advantages and production efficiencies in all critical item of modern living. By virtue of its limited natural resources, except for crude oil, and because of the many hindrances to diversifying its GDP, Saudi Arabia is heavily dependent on imports of goods and skilled labor from the USA, Europe and Japan. A boycott by the exporters of, among others, automotive and agricultural machinery, medical and pharmaceutical apparatus, telecommunication equipment, computer hardware and software, airplanes, spare parts and experts to operate and maintain all these could be as detrimental, may be more so, to Saudi national security than wheat boycott. Indeed, withholding shipments of spare parts

and experts for the desalination plants that provide Saudi cities with most of their drinking and household water could be catastrophic.[35]

The second reason is that sustained food independence in Saudi Arabia is impossible to achieve, as discussed in Section 7 above. High rates of population growth in a country of limited non-renewable water resources will lead eventually to depleting its aquifers, thus eliminating forever the hope of growing domestic foodstuffs again.

8.B Settlement of the Bedouins

In 1968 the Regulation for Fallow Land Distribution was promulgated. It was intended to settle the Bedouins. The evidence shows, however, that a relatively small amount of land was distributed during the first twelve years of the Regulation. If the purpose of the new law were to settle the Bedouins the size of the distributed land between 1968 and 1980 should have been greater. By the end of 1975, the government distributed 48,500 hectares of fallow land (SAMA, 1976: p.60). As of 1980, the total was still 123,163 hectares distributed to 19,421 individuals and 87 agro-business projects (SAMA, 1981: p.66). The speed accelerated during the 1980s. 373,580 hectares were distributed between 1980 and 1992 (496,743 hectares as of the end of 1992 – 123,163 hectares in 1980) to 74,196 individuals (SAMA, 1992: p.97). Since 1992, the pace of land distribution to individuals slowed down, 107,811 hectares by the end of 1999 (604,554 hectares in 1999 – 496,743 hectares in 1992) benefiting 93,432 individuals (SAMA, 2001: p.230). The history of this law suggests that its purpose evolved to increase foodstuffs production.

8.C Enriching the ruling elites

[35] In 1983, there were 16 desalination plants in Saudi Arabia with total daily capacity of 1.532 million m3, or about 559.2 million m3 per annum. By 2000, the number of the plants increased to 30 with a daily capacity of 2.877 million m3, or about 1.05 billion m3 per annum (Altukhais, 2002: table 1).

The Saudi ruling elite is composed of four groups. They support the 4,000 or so members of the ruling family in return for privileges and benefits. These are: the religious establishment, the tribal leadership, the major merchant families and the military class. The first group lends the regime religious legitimacy and uses its spiritual influence to help it control society. The second and third groups control the rank and file members of the business and tribal communities. This structure is particularly important in a country with no civil society organizations, labor unions, political parties, student and women associations, social clubs and the like. The military class defends the regime against local dissent. It is thought that Saudi desert agriculture was a scheme to enrich these groups. Such might be deduced from:

8.C.1. Growing considerably more wheat than the amount needed for domestic self-sufficiency. In 1992, wheat production reached 4.1 million tons for a population of 16.2 millions, more than double local needs.

8.C.2. The early participants in Saudi desert agriculture were business entrepreneurs, not professional farmers. They were absentee owners with little or no experience in farming. Over the millennia, severe aridity prevented the development of settled agricultural communities in the Arabian Desert of any size. Farming is alien to the desert habitat and the culture of its peoples. The promise of high financial returns from government subsidies to wheat growing enticed some of the country's businessmen to underwrite the risk of the new venture in the early 1980s. They imported the resources needed for the new enterprise from around the world, the engineers, mechanics, farm managers and laborers along with those giant 1000-foot-arm pivot irrigation systems, pumps, tractors, harvesters, seeds, chemicals and fertilizers.

The new investors needed to have good investment acumen and business experience. They also had to be financially sound, with substantial landholdings. Mainly

powerful businessmen,[36] especially in the Riyadh and Qasim region in the Central Province possessed these prerequisites. In 1998, the share of this Province of the overall Saudi cropping area was 49%. It became 42% in 1999 and 43% in 2000 (SSY, 2001: p.511).[37] Other Saudis, including the beneficiaries of the fallow land law, did not have the financial means, managerial skills or land size for wheat growing.[38] Between 1980 and 1992, of the overall increase in the irrigated area of 962,000 hectares [1.571 million hectares in 1992 – 609,000 hectares in 1980 (Table 2)], only 373,580 hectares, or 33% may be attributed to the 1968 land distribution law. The rest belonged to the country's business elites.

9. An observation on Saudi water use in agriculture

As the chapter on Saudi desert agriculture eventually reaches its end, a footnote in the long sweep of history will, nonetheless, remain. It will tell a side story to the Saudi oil bonanza. This is the tale of the one-generation that spent tens of billions of dollars from its newly found oil wealth (plus other un-quantified subsidies) on the unnatural endeavor of trying to make the desert bloom. The chapter will also tell the story of the one Saudi generation that ushered unsustainable environmental politics to its desert habitat. It consumed 300 billion m3 of mostly non-renewable water reserves in return for growing cereals, alfalfa, meat and milk in the forbidding sun of the Arabian Desert.

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[36] Among these were four of Saudi Arabia's reputedly richest businessmen, the Alrajhi brothers of Bukairia, Qassim. Their interests span banking, real estate, building materials, poultry farming and a wide range of manufacturing industries. In the early 1980s, they added wheat growing. Soon, two brothers became the largest wheat producers. Alrajhi's businesses in every field are among the largest in the country. For example, their flagship banking entity in the early 1980s was the Alrajhi Company for Currency Exchange and Commerce, a partnership of the four brothers that finds its roots in the 1940s. In 1988, it became Saudi Arabia's only publicly held Islamic bank, Alrajhi Banking and Investment Corporation. As of 12/31/2000 the Bank had shareholders' equity of 1.7 billions, market capitalization of US$12 billions (SAMBA/MEED Investor's guide, 2001) and over 450 branches. A poultry farm, established in the mid 1980s, owned by one of the brother, was thought to be the largest contiguous factory of its kind worldwide. These investors were attracted to wheat growing on a large scale by virtue of government subsidies.

[37] In 1998, the cropping area in the Central province was 553,890 hectares out of a total of 1.13 million hectares. In 1999 it became 512,505 hectares out of a total of 1.226 million hectares. In 2000 it was 485,242 hectares out of a total of 1.12 million hectares (SSY, 2001: p.511).

[38] Under the terms of the Regulation individual cultivators were granted "not less than 5 hectares and not more than 10 hectares" (SAMA, 1976: p.60). Such size land was too small for efficient wheat farming.

What was the instrument that enabled this situation to develop? The answer is that it developed as a result of government subsidies to desert irrigation. Subsidies distort the efficient workings of markets. They cause resources to be misallocated. The above analysis shows that under current international prices for agricultural crops, had Saudi Arabia not subsidized desert irrigation, the cost of growing unsubsidized agricultural crops would have been much higher than the market prices for similar imports. This could have led capital funds to be deployed away from loss making desert irrigation schemes into more rewarding industries, provided that there were no protective tariffs in favor of local produce. It would also have preserved the country's non-renewable aquifers.

References

Allan, Tony, 2001, *The Middle East Water Question – Hydropolitics and the Global Economy,* I. B. Taurus.

_____, 2001, *Virtual Water- economically invisible and politically silent- a way to solve strategic water problems,* International Water & Irrigation, Vol. 21, No. 4.

Abdrrahman, W, "Energy and Water in Arid developing countries, Saudi Arabia, a case study" in *Water Resources Development,* Vol. 17, No. 2, 2001.

Altukhis, Ali bin Saad, Vice Minister, Ministry of Agriculture and Water affairs of Saudi Arabia. A Paper entitled *The future of Water Resources in the Kingdom of Saudi Arabia* presented at a conference organized by the Ministry of Planning in Riyadh (October 19 – October 23, 2002).

Arab News Newspaper, Riyadh, Saudi Arabia, September 27, 2002, *Gulf War cost Riyadh $80 billion: Prince Naif.*

_____, December12, 2003, *Ban on Allocation of Land for Farming.*

Asian Development Bank, Manila, Philippines, "Guidelines for the Economic analysis of Projects." Appendix 6.

Berthke, Craig M. Department of Geology, University of Illinois, "M. King Hubbert and the Rise of Quantitative Hydrology." A paper presented at a conference entitled *M. King Hubbert at 100: The Enduring Contributions of Twentieth-Century Geology's Renaissance Man*, Monday, November 3, 2003, Washington State Convention and Trade Center:

Campbell Colin J. and Laherrere, Jean H. "The end of cheap oil", *Scientific American,* March 1998

Europa Publications, 49th Edition, *The Middle East and Africa 2003, Saudi Arabia*. London.

Food and Agriculture Organization of the United Nations- http://www.fao.org/ FAOSTAT Agriculture Data- http://apps.fao.org/page/collections?subset=agriculture

Japan International Cooperation Agency (JICA), *The Study on Water Resources Development in the Northwestern and Central Basins in the Syrian Arab Republic (Phase I),* Volume III: Supporting Report, October 1997.

Hoekstra, A. Y. and Hung, P. Q. *Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade*, Proceedings of the

International Expert Meeting on Virtual Water Trade, edited by A. Y. Hoekstra, Delft, The Netherlands, 12-13 December 2002.

Hubbert, M. King, "Energy from Fossil Fuels," *American Association for the Advancement of Science,* February 4, 1949 Vol. 109, pp.103 – 109.

Ministry of Planning, Kingdom of Saudi Arabia, *Statistical Yearbook,* Thirty Seventh Issue, 2001.
_____, *Achievement of the Development Plans, Facts and Figures*. Nineteenth Issue 1970 – 2001, Published in 2003.

Richards, A. and Waterbury, J., 1998, *A Political Economy of the Middle East,* Westview Press.

The New York Times, January 26, 2003. *Saudis Worry as They Waste Their Scarce Water,* by Graig Smith.

Saudi American Bank, Brad Bourland, Chief economist. *The Saudi Economy in 2002,* February 2002. Riyadh, Saudi Arabia.

Saudi Arabian Monetary Agency, Annual Reports.

Statistical Abstract of the United Sates of America: 2000.

Saudi Water Net, King Fahd University for Petroleum and Minerals website www.kfupm.edu.sa/saudiwaternet/

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