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Diesel Subsidies and Yemen Politics: Post-2011 Crises and their Impact on Groundwater Use and Agriculture

Adel Al-Weshali

Water and Environment Centre, Sana'a University, Sana'a, Yemen; drweshali@yahoo.com

Omar Bamaga

Center of Excellence in Desalination Technology, King Abdulaziz University, Jeddah, Saudi Arabia; obamaga@kau.edu.sa

Cecilia Borgia

MetaMeta Research, AJ 's Hertogenbosch, the Netherlands; cborgia@metameta.nl

Frank van Steenbergen

MetaMeta Research, AJ 's Hertogenbosch, the Netherlands; fvansteenbergen@metameta.nl

Nasser Al-Aulaqi

Water and Environment Centre, Sana'a University, Sana'a, Yemen

Abdullah Babaqi

Water and Environment Centre, Sana'a University, Sana'a, Yemen; asbabaqi@y.net.ye

ABSTRACT: Groundwater is the main source of agricultural and municipal water and contributes 70% of total water use in Yemen. All aquifers are depleting at a very high rate owing to combined effects of a host of socioeconomic, institutional and climate-change factors. The government policy on diesel subsidy was largely believed to be one of the significant factors which stimulated large-scale pumping of water for irrigating water-intensive cash crops such as *qat*, fruits, and vegetables. A rapid field assessment was conducted between June and December 2011 in six different regions of the country to analyse the impacts of the severe diesel crisis that accompanied the political turmoil of 2011 on groundwater use and agriculture. The study highlighted winners and losers in the process of adapting to diesel shortage and high diesel prices. Farmers' responses differed according to their social status, financial resources, and farming systems. Poorly endowed households partially or completely abandoned agriculture. Others abandoned farming of irrigated cereals and fodder, but practised deficit irrigation of fruits and vegetables, thus halving the consumption of diesel. Crop yields dropped by 40-60% in all surveyed regions. The intra-governorate transport halt due to the sharp increase in transport cost caused prices at the farm gate to drop. Only those farmers who could absorb increases in diesel prices due to high return:cost ratios, higher drought tolerance, stable prices (qat), and access to alternative sources of water could cope with the diesel crisis.

KEYWORDS: Groundwater, diesel subsidy, diesel crisis, irrigated agriculture, Yemen

INTRODUCTION

Groundwater aquifers are the primary water resource for agriculture and municipal water use in different regions of Yemen contributing to about 70% of total water use of the country with estimated annual withdrawals of 2.5 billion cubic metres (Bm^3) (World Bank, 2010). Since the late 1980s, it has been recognised that the dependency of the country on groundwater was unsustainable due to continued and accelerated depletion of aquifers. At the national level, the rate of groundwater depletion is currently twice the recharge rate; however, some stressed aquifers are pumped at a rate approaching four times the natural recharge rate. The problem of aquifer depletion was aggravated by the absence of a proper water governance system which adapts to the new reality of market-driven agriculture and tube-well technology. Although some forms of groundwater governance were introduced in the mid-1990s, the government's ability to control and properly manage extraction of groundwater was weak, and on the other side, the policies and incentives that stimulate inefficient use of water for irrigation still existed (Hellegers et al., 2011). Also, the strong traditional community-based water management practices in some areas could not help in conserving groundwater because these practices served basically to reduce conflicts and provided more reliable and equitable access to water (Taher et al., 2012). The government policy on diesel subsidy was largely believed to be one of the significant factors which stimulated high rates of aquifer depletion in addition to other policies that promoted local production of fruits, vegetables and *qat*[1] through restriction of imports. Until 2011, Yemen was among the countries with the lowest fuel prices at the pump in the world. Diesel engines are used throughout Yemen as an energy source for groundwater pumping. The availability of diesel at a very low price promoted large-scale pumping and inefficient use of groundwater for irrigating water-intensive cash crops such as the narcotic qat, citrus fruits, mangoes, bananas and high-value vegetables (World Bank, 2003; Scott and Shah, 2004).

Yemen has a very long history of irrigated agriculture where surface runoff irrigation, as one of the earliest irrigation techniques in the region, has been practised for more than 5000 years (van Steenbergen et al., 2010; Ward, 2014). However, starting from the 1960s there has been a rapid shift from traditional surface runoff irrigation to groundwater irrigation. The groundwater-irrigated crop area increased from 37,000 ha in 1970 to 400,000 ha in four decades (1970-2012) (MAI, 2014). This is the equivalent of a third of the total cropped area (Al-Eryani et al., 2011). The rapid spread of new irrigation technology has not only altered irrigation practices but also changed the cropping patterns – the area under vegetables and fruits has shot up from 39, 000 ha (3% of the total cropping area) in 1970 to 184,000 ha (14% of the total cropping area) in 2010, and the production of high-value fruit and vegetables has increased by 20 times, from 40,000 tons annually in 1970 to 800,000 tons in 2010. Full or supplemental well irrigation now accounts for two-thirds of the value of crop production, and despite ever-increasing pumping depths, groundwater use remains currently financially profitable in many areas and for many crops (World Bank, 2010).

In 1966, under a significant pressure of the World Bank, the government initiated an economic reforms policy aimed at stabilising and restructuring the economy (Al-Batuly et al., 2011). The gradual removal of all types of public subsidies including fuel subsidies, which are in the form of revenue foregone by under-pricing fuel, was a key element in the stabilisation policy. Fuel subsidies drain a great portion of the fiscal budget and represent an indirect incentive that drove groundwater overdraft. However, the government was reluctant to increase the diesel price to import parity price. Starting

[1] An evergreen shrub, *Catha edulis*, grown in western mountainous areas of Yemen whose green leaves are commonly chewed by adults for its stimulant effects.

from 1996 and up to the beginning of 2011, the diesel price was hesitantly increased from YER10[2] to YER50/litre (l), which is still far behind the import cost.[3] The immediate negative impacts on the poor and fears of political unrest were the main concerns that constrained the government undertaking swift reforms in fuel prices.

The petrol and diesel supply line goes through various phases that depend first on the availability of cash to purchase the oil derivatives from the international market and the two local refining companies, Aden Refinery Company and Yemen Oil Refining Company at Marib. The total production capacity of the two refineries is only 50,000-70,000 tons of diesel per month, versus a country's monthly consumption of 250,000-300,000 tons. The rest required to satisfy these needs is imported where the government allocates a cash outlay from its budget to pay for fuel imports at the import parity price, and then provides the fuel to the consumers at lower prices (Yemen Times Newsletter, 2014). In the wake of the Arab Spring, Yemen was engulfed in a severe political crisis starting in February 2011. The crisis resulted in violent conflicts and weakened the government control over roads and crude-oil pipelines. The security risks have destabilised the fuel supply chain where fuel imports had ceased and the local refineries were partially or completely shut down. The diesel crisis thus emerged quickly in the form of both supply shortages and sharp price increases. Considering a series of successive records of fiscal deficits and the threat of an impending collapse of the national economy, the government had no option but to lift the fuel subsidy completely. Initially in 2012, the diesel price was increased to around 50% of its parity price and more recently in July 2014, the price was set on par with the parity price. The recent price hike brings about an increase of 95% in diesel price which provoked unprecedented demonstrations and political unrest, led by the Houthi movement, an armed rebellion outfit. Finally, the riots forced the government to revise the price increases. However, the political situation deteriorated quickly and the new developments brought the country into a violent armed conflict and the political transition process was jeopardised.

Groundwater is a principal source of water for irrigation in many countries in South Asia, the Middle East and North America. In the Arabian Peninsula, groundwater accounts for 84% of total water withdrawals (Siddiqi and Anadon, 2011), while in India, the area irrigated by groundwater is more than that by all the other surface irrigation systems combined (Seckler et al., 1999). Pump sets driven by diesel engines or electricity are used extensively for groundwater pumping and, hence, energy is used in significant amounts to access water. Depending on the depth of the well, pumping groundwater requires from 0.4 to 0.8 kWh per cubic metre of water (Abderrahman, 2001). The problem of inefficient groundwater energy nexus is not unique to Yemen. Many of the largest users of groundwater such as China, India, Pakistan and Mexico and nearly all of the countries of the Middle East and North Africa are depleting their groundwater resources and the low energy pricing was cited as the primary driver of the groundwater overdraft (Scott and Shah, 2004).

Based on a rapid field survey matched with a screening of relevant secondary data, this study sets out to assess the impacts of the last diesel crisis that accompanied and followed the political change of 2011 on groundwater use, agriculture and rural livelihoods. In light of this, the present study is a timely attempt to decipher the role of the diesel subsidy for agricultural development and the rural economy in general, and the implications its removal would have on groundwater use, agriculture and rural development, in particular.

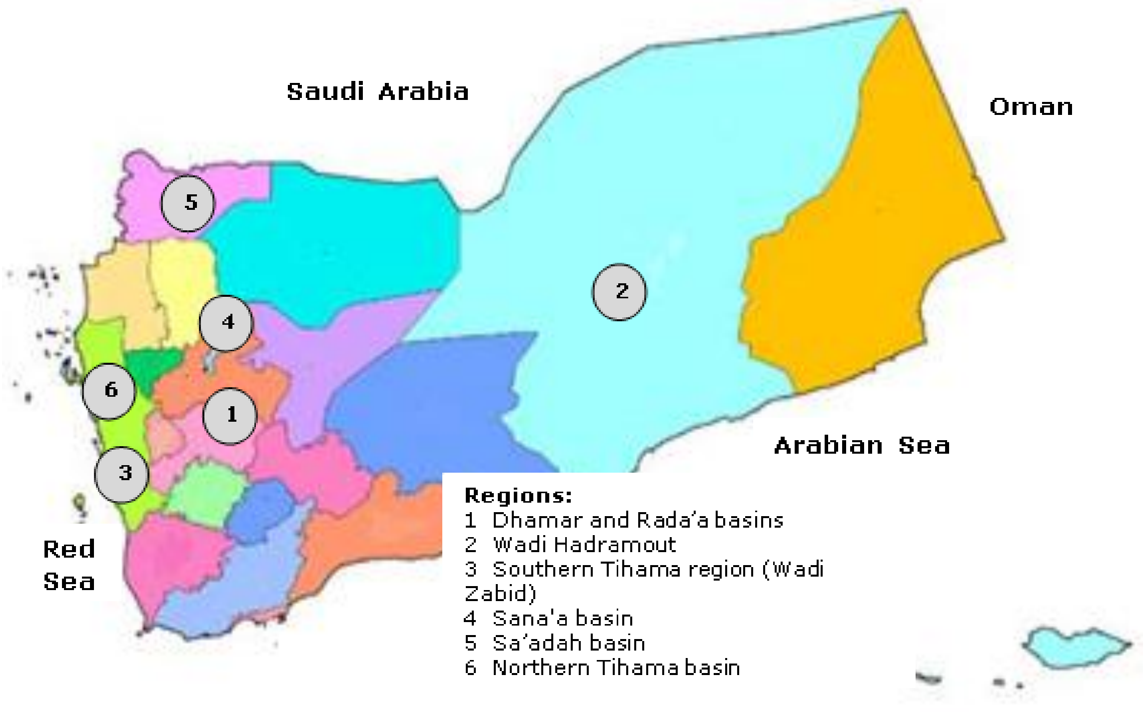
[2] 1YER=0.0040 EUR as of January 2015. However, throughout this period the depreciation of the currency and the associated high inflation rates, which averaged more than 11% annually, wiped out part of these domestic price increases (IMF, 2013).

[3] Since the mid-1990s the value of the Yemeni Rial has been stable at the level of approximately YER 215 against the U.S. dollar.

Methods

This case study was carried out under a multi-country research project titled Groundwater in the Political Domain funded by the Netherlands Organization for Scientific Research (NWO). Both primary and secondary data were used in this study. Primary data were collected through a rapid field assessment conducted between June and December 2011 in six different regions of the country (shown in Figure 1), in collaboration with research associates positioned in each selected region. Each region presents different climatic, socioeconomic, agrarian, and farming conditions, as well variable levels of groundwater dependence for irrigation as presented in Table 1.

Figure 1. Location of surveyed regions.



In each region, data were collected using four sets of questionnaires, namely for farmers, for owners of fuel stations, for wholesalers of agricultural products and for diesel vendors. Altogether 36 farmers were visited in all regions and the size of a farm varied from 4 to 63 ha (see also Table 1). Farmers were asked about changes in yields of different crops, irrigated area, irrigation and pumping hours, and diesel consumption and other responses to the diesel crisis. The amount of average diesel consumption in surveyed farms for each season before the occurrence of the diesel crisis was calculated on the basis of the total quantity of diesel consumed per farm relative to the irrigated area. Owners of fuel stations and private vendors of diesel were interviewed for information on diesel prices on the black market. Finally, wholesalers of agricultural products were asked for changes in prices of vegetables and fruits.

Secondary data were collected from relevant government sources including Yemen Petroleum Company (YPC), Central Statistical Organization (CSO) and the General Division of Agriculture Statistics (GDAS) in the Ministry of Agriculture and Irrigation (MAI) as well as from the published literature.

Groundwater use and agricultural development

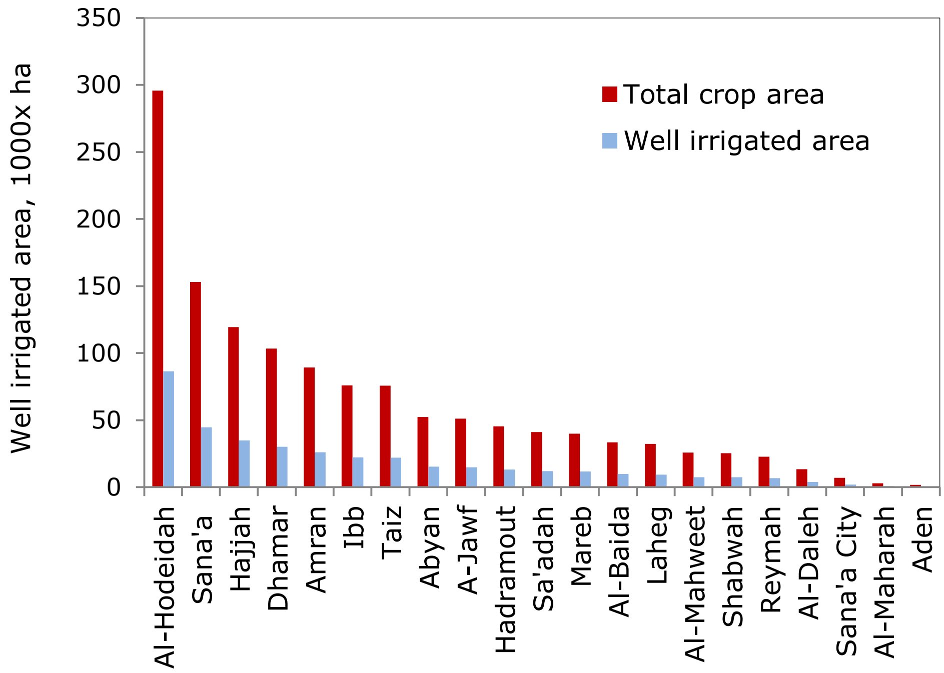
A few distinct features, namely its diversification, strong market orientation and dependence on irrigation, particularly from groundwater aquifers, characterise Yemen agriculture. Although two-thirds of the area of Yemen is a hyper-arid desert with less than 50 mm annual rainfall, the climate of the remaining area varies from arid to semiarid. Average annual rainfall above 250 mm occurs only in the mountainous regions, where most of the population is concentrated (World Bank, 2010). The total agricultural land is 1.66 million ha, which represents only around 3% of the total area of the country, while the cultivated area varies from 0.98 to 1.5 million ha according to the amount of annual rainfall (Hellegers et al., 2011). More than two-thirds of the agricultural land is located in the mountainous regions and western Tihama Plain i.e. governorates of Al-Hodeidah, Sana'a, Hajjah, Dhamar, Ibb and Taiz (Figure 2) (MAI, 2009).

Table 1. Characteristics of the study regions.

Region	Characteristics	Number of farmers visited
1. Dhamar and Rada'a basins	Located in the western highlands, characterised by intensive well irrigation from deep aquifers. Main irrigated crops: qat and vegetables	8
2. Wadi he Hadramout	Farming is highly dependent on well irrigation in the farms located around Shibam City. Main irrigated crops are sorghum, wheat, dates, tomatoes, potatoes, onions, and alfalfa.	6
3. Southern Tihama Plain (Wadi Zabid)	Wadi Zabid counts as one of the most important agricultural regions in Yemen. Main irrigated crops are mangoes and bananas (high economic value), cereals, legumes, vegetables, and fodder crops including alfalfa.	5
4. Sana'a Basin	This is the most water-stressed basin in the country. Main irrigated crops are qat, grapes, and vegetables.	5
5. Sa'dah Basin	This basin is a low-lying inter-mountain plain located at the extreme north of Yemen, characterised by a semiarid climate. Intensified farming of apple, pomegranate grapes and citrus fruits irrigated mainly with groundwater.	5
6. Northern Tihama Plain	Located on the western coastal plains and is characterised by well irrigation and relatively poor farmers growing millet, sorghum, tomatoes, onions, bananas, oranges, cotton, and sesame.	7

Agriculture depends on three sources of water: rainfall, groundwater, and runoff (base flow and flood flows). Flood-based/spate irrigation, whereby floodwater from mountain catchments is diverted from riverbeds (wadi) and spread over large areas, has a very old tradition in Yemen and plays an important role for agricultural development and food security. However, it is with the intensive development of groundwater since the late 1970s, previously a supplemental source of irrigation, that water-needy cash crops, such as fruits, vegetables, tobacco, and qat, could be irrigated throughout the year. Today, agriculture accounts for about 90% of the country's groundwater use (Al-Asbahi, 2005). Unregulated, deep groundwater exploitation became possible because of new technologies and subsidised diesel prices, money flows from workers in nearby oil-rich countries that was often reinvested in land acquisition (Ward et al., 2001), the government policy that promoted expansion rather than efficient use and sustainable management of water and the agricultural development assistance projects funded by the World Bank and other donor institutions. As a result, in the last three decades, Yemen has fallen into a very serious water crisis whose causes are primarily the rising water demand as population and market-led agriculture develop rapidly.

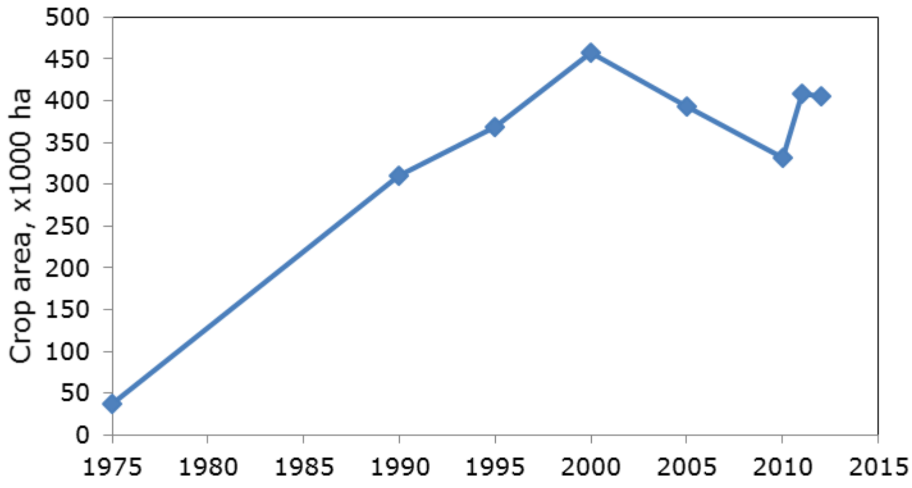
Figure 2. Comparison of cultivated area and well-irrigated area by governorate (Data source: MAI, 2009).



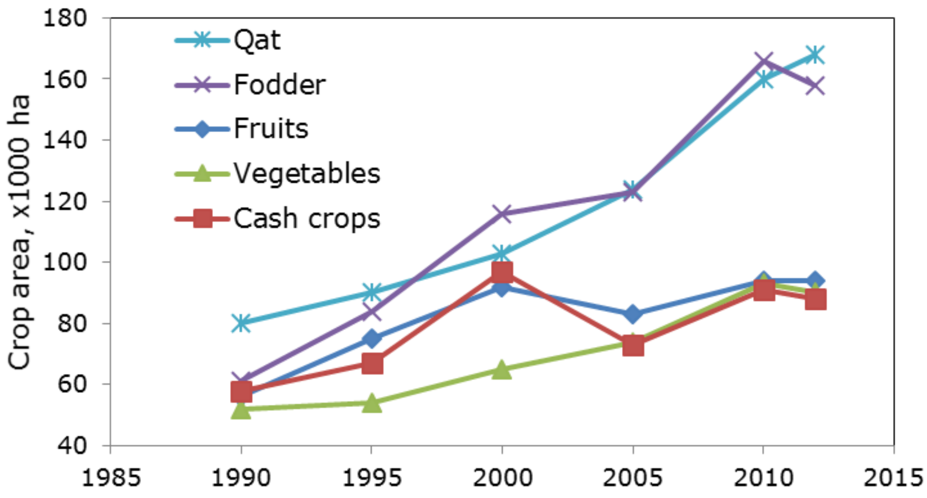
Figures 3a and 3b clearly show the growing trend of irrigated crops and well-irrigated area and underscore the implicit relationship between the two. Figure 3a shows a steady increase in well-irrigated area with fluctuations in the trend after the year 2000. On average, the well-irrigated area in the different governorates is estimated at 30% of the total cultivated land, yet this area represents 55% of the total irrigated in the country (Figure 2). It should be noted that some crops that are completely rain-fed in some areas, are partially or fully irrigated with pumped water in other areas. In general, qat, vegetables and fruits are always irrigated. Figure 3b indicates that between 1990 and 2010 the area of main irrigated crops cultivated, fodder, qat, vegetables, fruits, and other cash crops (e.g. cotton, coffee), increased by 172, 100, 79, 68 and 57%, respectively (MAI, 2013). The figure also shows that qat and vegetables maintained a constant growth rate throughout the analysed period. Qat makes up the largest share of irrigated land, covers 15% of the total cultivated area, and uses about 40% of total water consumption (Gatter, 2012), although other estimates suggest qat irrigation is responsible for 70% of groundwater depletion (Giesecke, 2012).

Considering the small size of landholdings in Yemen and high return of specific irrigated crops, the rapid expansion of well-irrigated agriculture was accompanied by excessive and uncontrolled well drilling wherever productive aquifers could be found. Thirty years after the first tube well was drilled in the country in late 1960s, the number of tube wells has exceeded 50,000 and reached 70,000 by 2009 (NWRA, 2009). Yemen's previous minister of water estimated that 99% of all water extracted is unlicensed and that 800 drilling rigs are operating illegally (Boucek, 2009).

Figure 3. Growth of well-irrigated area (a) and cultivated area for principal irrigated crops (b) (Data source: MAI, 2013).



(a)



(b)

The density of wells per unit area varied between regions, with some basins reaching the state where no more wells can be drilled either due restrictions imposed by the government or because of the local community governance rules (van Steenbergen et al., 2011). The Sana'a Basin exemplifies these extreme water stresses. The number of wells in the basin went up from a few hundred in 1973 to around 6000 wells in 2001 (Al-Hamdi, 2000) and 8000 wells in 2009 (NWRA, 2009), while the annual groundwater abstraction increased from 60 to 370 Mm^3. Of this amount, around 85% is for agricultural use, mainly to irrigate qat and grapes. The water balance of the Sana'a Basin indicates abstractions to be five times higher than recharge – 270 Mm^3 against 51 Mm^3 (JICA, 2007). Similar but less severe examples can be found in other parts of the country: 34 Mm^3 against 18 Mm^3 in Wadi Ahwar (Hydrosult, 2008) and 235 Mm^3 against 115 Mm^3 in Wadi Hadramout (Komex, 2002).

DIESEL SUBSIDY AND GROUNDWATER ACCESS: WINNERS AND LOSERS

The steep and steady expansion of well-irrigated area was largely the outcome of the diesel policy pursued by the state since the 1970s. Following many other developing countries, Yemen heavily subsidised fuel and maintained a flat price irrespective of price fluctuations in the international fuel market (Figure 4[4]). The fuel subsidy bill became a heavy burden on the government spending due to continuously increased domestic fuel consumption and the rise of international fuel prices. Despite several governmental reforms to reduce fuel subsidies since the 1990s, the subsidy bill in the budget was still large at around 10% of the GDP in 2012. This amount exceeds the total of infrastructure and social expenditures (IMF, 2013). In 2007, the fuel subsidies drained more than 20% of the government budget and more than the total spending on education, health and social transfers combined (Breisinger et al., 2012).

Figure 4. Reforms of consumer diesel prices (in YER/l) since 2005 compared to the international prices. Source: IMF (2013).

In 2009, diesel accounted for about 53% of the total volume of consumed fuel, with 3.96 billion l, but absorbed 69% of the total fuel subsidy. Diesel is the main energy source in transportation, agriculture, industry, and services. Agriculture alone consumes about 12% of diesel, mostly for irrigation. Fuel is the single largest expenditure item for agricultural production despite the diesel subsidy. The transport sector as the biggest consumer of fuel (40% of total volume) constitutes also an important input for production in other sectors (Breisinger et al., 2012). The diesel subsidy not only drains government revenue but also distorts commodity prices, and makes water pumping and trucking costs artificially low, thereby giving farmers no incentive to conserve water (Sharp, 2011).

Access to groundwater and diesel subsidy in Yemen is highly differentiated and driven by social, power and economic statuses. Except for drinking-water wells, which are managed by local public authorities and local corporations or community organisations, groundwater is unrestrictedly accessed through privately owned wells. Despite the Water Law of 2000, which introduced the licensing of wells,

[4] The fuel cost is the sum of fuel import cost (CIF import price at the port), costs of distributing fuel to domestic consumers (storage and distribution margins), and net fuel taxes (IMF, 2013).

making groundwater development on paper no longer a free-for-all, in practice, water rights are still largely associated with landownership, which is private (van Steenbergen et al., 2011). In addition, due to the relentless drop in water tables, only well-off households have the financial ability to install deep tube wells (alone or in participation with others). With the absence of any government programme to support poorer farmers to access groundwater, well-off farmers also benefit disproportionately from the diesel subsidy both directly (because they consume more energy than poorer households) and indirectly (because they consume more energy-intensive products and services). Overall, about 40% of fuel subsidies go to the richest 20% of households while only 25% go to households in the bottom 40% (IMF, 2013). Breisinger et al. (2012) have shown that the use of diesel for agriculture is concentrated in the two-third top income households. In rural areas, 29.8% of households in the top two-third report diesel use for agriculture (and who use 200 l a month for this purpose), as opposed to only 1.7% of rural households in the poorest one-third of households (who use only 25 l a month).

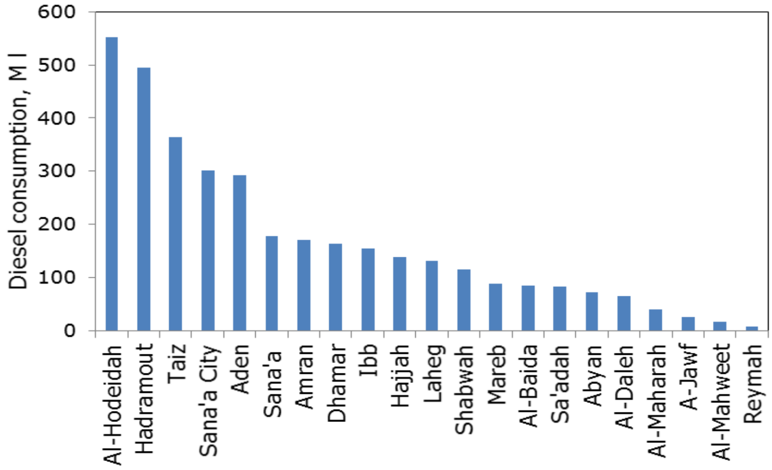
The distribution of wealth, and thus access to groundwater use, are strictly related to access to power and patronage. The ruling leadership, particularly before 2012, has always sought to extend patronage to all elites in the country to secure their adherence and compliance (Clark, 2010; Moore, 2011; Phillips, 2011; van Steenbergen et al., 2015). Generous resource routing to power elites through the patronage mechanism has reinforced their political and economic status even more. This allowed tribal leaders for instance, main beneficiaries of the diesel subsidy, to extensively develop groundwater resources through deep tube wells.

The link between groundwater use and qat cultivation is strong and a main additional source of inequity. Those who have most access to the first are also those who pursue the second. Qat, absorbing 40% of total water use, is the prime cause for dwindling groundwater resources. By this, it is constraining the access to irrigation water for poorly endowed farmers, thus threatening their livelihoods. Although qat cultivation has improved revenues of many rural farmers, most of the production is still owned and controlled by tribal leaders, military officials, and political elites, fuelled by the patronage system. This made any attempts by the governmental side to reduce qat cultivation for the sake of water security quite ineffective.

Around 85% of qat production comes from five governorates located only in the highlands region of the country, which include Sana'a, Amran, Dhamar, Ibb, and Hajah (MPIC, 2010). The average annual income of a qat farmer has been estimated to exceed YER375,000, which is more than twice the national average of per capita income. In 2007, the annual turnover of qat reached YER254 billion, around 10% of the GDP and one-third of agricultural GDP. Qat is not only an easy marketable crop but is also the most profitable crop: five times as profitable as grapes and 20 times as profitable as potatoes (SMEPS, 2009; Hellegers et al., 2011).

Preferential access to diesel subsidy by power elites occurs indirectly by their lion's share in groundwater use (through deep wells and for qat irrigation), and directly, as diesel subsidy is used as another source of patronage (van Steenbergen et al., 2015). Subsidised diesel triggered smuggling of diesel to neighbouring countries in the Horn of Africa or transfer of the purchased diesel before it enters Yemen by the powerful elite, who resold it at the international market at a profit (Phillips, 2011). A study conducted by the World Bank (2005) reported as much as 30% of total diesel consumption was smuggled. According to Phillips (2011), in 2008, at least 50% of the public money allocated to the diesel subsidy (equivalent to 12% of the GDP) was captured by elites through diesel smuggling practices alone. van Steenbergen et al. (2015) suggested that the tripling of diesel import between 2000 and 2007 cannot be explained by increased demand within the country and relates more to an increase in elite capture of significant amounts of imported diesel for their benefit. Another clear evidence of diesel smuggling is the extremely high levels of apparent diesel consumption in coastal governorates especially in Wadi Hadramout and Al-Hodeidah (Figure 5). Diesel consumption in governorates can be related to a number of parameters such as population, well-irrigated area, number of vehicles, and volume of industrial production.

Figure 5. Diesel consumption in governorates in 2010.



Note: M l on the Y axis label indicates million litres.

Figure 6. Diesel consumption in governorates per capita for 2010.

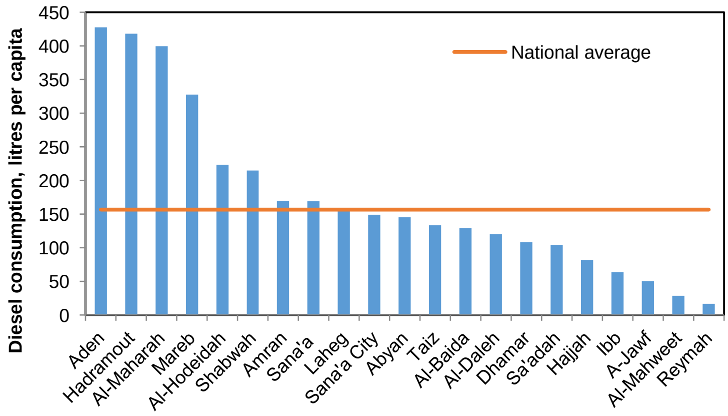
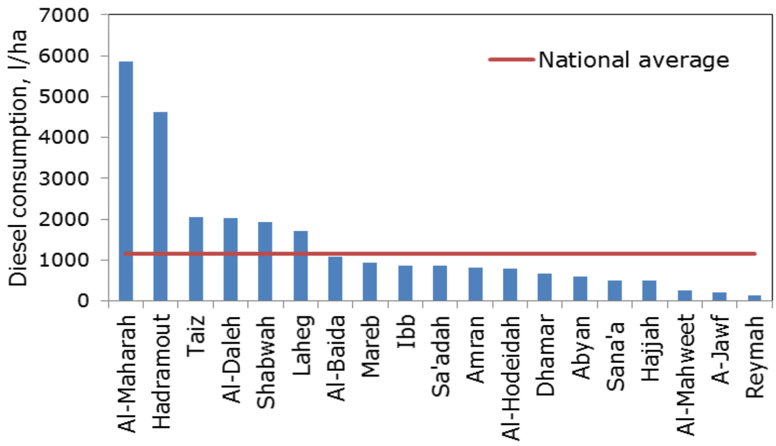


Figure 7. Diesel consumption in governorates per well-irrigated ha for 2010.



The diesel consumption per capita and per ha of well-irrigated area could be taken as reasonable indicators of relative diesel consumption. The apparent per capita diesel consumption in coastal governorates is well above the national average (Figure 6). According to the 2010 fuel consumption data, per capita diesel consumption was 418 l for Wadi Hadramout and 400 l in Al-Maharah, compared to the national average of 157 l. Values of diesel consumption per ha of well-irrigated area were calculated assuming that 12.4% of the diesel is used in the agriculture sector for irrigation and other related operations as have been estimated by Breisinger et al. (2012). Again, Figure 7 shows that Al-Maharah and Wadi Hadramout governorates are far ahead in terms of diesel consumption per ha of well-irrigated area. Common sense suggests that the values of diesel consumption indicators are not true and hide the fact that significant diesel smuggling activities are carried out through these coastal governorates.

DIESEL CRISES AND THEIR CONSEQUENCES

Diesel crises in Yemen are not new and occurred several times during the last two decades. However, the one that started in March 2011 and continued until the end of 2011 was of unprecedented severity. Whereas past diesel crises were mostly related to financial crises, elite's capture of the state budget (van Steenbergen et al., 2015), and government's threats to increase diesel prices, the one of 2011 was, at least partly, unleashed and exacerbated by the political and social unrest that hit Yemen in the wake of the Arab springs since the beginning of 2011. Several concurrent factors contributed to the escalation of events leading to the 2011 diesel crisis. Some factors are structural while others are specific to the political crisis of 2011. Diesel smuggling to neighbouring countries is believed to be a key reason for the continuous diesel shortage, which has deleterious repercussions on the livelihoods of those most in need. Illegal diversion of diesel allocations from one governorate to another and/or from one sector to another is yet another factor intrinsic to the diesel subsidy system. The multiple diesel pricing mechanism in place is a stimulus for industrial and commercial business to obtain diesel intended for residential users at a cheaper price. Technical faults reducing production at the two national refineries and insufficient storage capacity at the various oil plants (both coastal and inland) also count as structural causes for diesel scarcity. Another reason is the chronic cash shortage leading to delayed payments of the diesel subsidy by the Ministry of Finance to the two refineries, and reducing fuel imports. The costs of the social unrest and armed confrontations of 2011 were an additional burden to the public budget, aggravating the default situation.

Citizens' response is generally immediate. The outspread of rumours of imminent fuel shortage and leaks of government's decision to raise diesel price pushes citizens into a 'rush for diesel' in large quantities for storage. The crisis that occurred in August-September 2008, which was one of the worst, followed an unexpected decision of the government to increase diesel prices for some sectors fivefold from YER35 to YER200/l. These sectors included steel, electricity and cement plants. As a result, many owners of diesel-fuelled businesses including bakeries and laundries, as well as small factories started buying large quantities of diesel to secure their longer-term needs. In June 2009, again, following a governmental announcement to introduce new distribution regulations for diesel based on actual consumptions and population density, a new diesel crisis occurred. In July 2010, another diesel crisis erupted few days after a new increase of diesel price.

Fluctuations in demand in different times of the year also contribute to intermittent diesel scarcity. For instance, on the advent of the month of Ramadan, the holy month for fasting, demands of gas and diesel increase as citizens buy large quantities to avoid possible diesel shortages during the Eid holiday. Similarly, diesel shortage followed a seasonal pattern, depending on crop demands for irrigation. With the onset of winter, irrigation requirements diminish, resulting in a decrease in the demands of diesel. Moreover, in some areas, such as Qa'a Jahran (plateau around Dhamar) winter is not a cropping season.

Qat farmers in Rada'a and in other cold regions stop irrigation during winter to avert frost formation on qat trees due to low temperatures.

What was new in the diesel crisis of 2011 was the situation of extreme instability caused by social and political disputes that allowed strengthening of armed groups of various backgrounds, i.e. tribal, partisan and terroristic, to bomb crude oil pipelines connecting the refineries of Marib and Aden, and block roads to seize gas and diesel trucks. These actions disrupted the supply of diesel to the different governorates and cities.

Emergence of a black market of diesel

Diesel shortages in Yemen have occurred several times in the past 15 years, but were usually short in duration. Until then, consumers managed to overcome diesel shortages without paying higher prices for it. Farmers used to face these crises by keeping reserves of about 2000 l diesel, which was just enough to overcome shortages for a few weeks. Since the diesel crisis of 2011 lasted throughout the year, farmers quickly exhausted their diesel stocks and started struggling to satisfy their diesel needs. The prolonged shortage of diesel provided a background for the occurrence of a black market of diesel, which was quite unusual in the history of diesel crises in Yemen. During the crisis period, diesel supply was intermittent and available only in a few fuel stations. As a result, long queues of cars were a common phenomenon everywhere and the wait could last from a few days to weeks even. These delays were often accompanied by tensions and violent outbursts that sometimes even resulted in deaths and injuries. The general lack of diesel on the supply side was aggravated by a sheer feeling of insecurity that pushed several, mostly powerful landowners, to buy large amounts of diesel (3000-4000 l per capita) to secure their private needs for a longer period, as they had learned from previous crises.

The survey points that diesel vendors involved in the black market are not traders by practice. They are for instance farmers, agricultural products retailers, taxi drivers, owners of water tankers, qat sellers, and jobless individuals who found this business rewarding. Several station owners reported that they bought diesel from the black market. Prior to the crisis, the average amount of diesel marketed by each fuel station was 12-13 tankers (capacity 57,000 l) per month, but during the crisis, the average marketed quantity decreased to only 2 tankers per month. The price of diesel found on the black market varied considerably according to the location and timing. In Dhamar, within just four months, the diesel price rose from YER50 to more than YER500/l at the apex of the crisis in May-June 2011, then declined to YER175/l at the end of 2011 (Table 2). In Sa'dah, the price skyrocketed from YER50 to more than YER300/l only in July 2011. During the same month, the increase in diesel price was less marked and reached only YER175 in Bani Hoshaish in the Sana'a Basin. In Wadi Zabid, the price of diesel varied in a wide range through 2011. In the peak of the shortage period, the price of diesel reached YER500/l (ten times the official price) but the average price was around YER300/l for all seasons. An increase in the price of diesel corresponded to an increase in the price of water sold by tankers. This water source is especially common among qat farmers in Rada'a. The price of a 50 m^3 water tanker rose up to YER25,000 during the diesel crisis compared to YER12,000 before the crisis.

Table 2. Diesel price in the black market from February till December 2011 in Dhamar – Rada'a basins (Data source: Dhamar branch office, NAWRA).

Month	February – April	May – June	July – October	November – December
Diesel price YER/l (USD)	100 (0.47)	500 (2.34)	300 (1.40)	175 (0.82)

The government adopted several measures to try to control the diesel black market and secure diesel supplies to basic public services such as drinking water, hospitals and bakeries. While prohibiting the sale of diesel on the roads by private vendors, the government also introduced a diesel rationing system managed by local councils according to which farmers could get one barrel of diesel (capacity 200 l) per week and transport vehicles with 60 l once every three days. However, the system was barely applied due to violent conflicts, which took place in many stations. Security forces were apparently not allowed to interfere either due to weakness or to avoid political complications. In some cases, arrogant individuals forced station owners to supply them with diesel by force, even without paying its cost in some cases. In Rada'a as in other areas, there was no control of any kind.

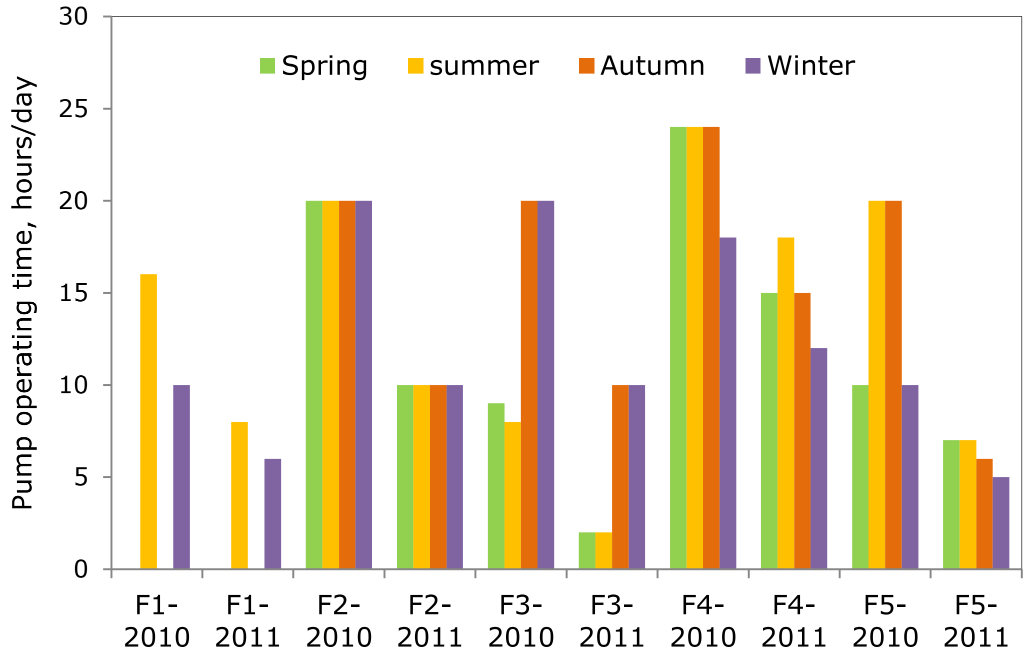
Ultimately, the success of governmental efforts to contain the black market of diesel was almost nil, especially outside main cities. Local government authorities proved unable and/or unwilling to control and regulate the distribution and price of diesel so that the informal market could thrive free of any restrictions. Diesel vendors remained key players in the diesel market. Each vendor could sell on average up to ten barrels per month (one barrel contains 200 l) as reported by the interviewed vendors in Bani Hoshaish, who also revealed that 80% of this diesel was bought by farmers. Diesel was also smuggled in from neighbouring countries, Oman in particular, and sold at high prices along the roads. Several informants reported cases of fraud, i.e. the selling of synthesised diesel that may damage engines.

Impact of diesel crisis on groundwater use, diesel consumption, and crop yields

As a result of the diesel crisis, in all five study regions, surveyed farmers reported losses of varying degree in terms of yields, product quality, income, and irrigated area due to the lack of fuel to pump groundwater for irrigation. Despite efforts by the local councils to regulate diesel distribution to farmers through coupons, the available diesel was still too little to supply farmers with the required amount to keep farming at a normal intensity. In response to diesel shortages and higher diesel prices and in order to reduce diesel consumption and pumping costs, farmers had no option left but to reduce daily pump operating hours and number of irrigations for certain crops (e.g. fodder and vegetables) while keeping adequate irrigation supplies for profitable crops such as mangoes and bananas. Farmers' responses differed according to their social and financial status, and the water requirements of their farming system. In Sa'dah, surveyed farmers reduced pump operating hours, on average, by 38, 36.5, 44, and 58% in spring, summer, autumn, and winter, respectively. For vegetables alone, pumping hours were reduced by 33%. By reducing pump operating time farmers achieved a proportionate reduction in diesel consumption. In Wadi Zabid, reductions in pumping hours were higher and on average 46, 49, 51, and 45% in spring, summer, autumn, and winter, respectively (Figure 8). As fodder was considered less preferential than fruit trees and also less profitable than fruits, its cultivation was either stopped altogether or it was watered under deficit irrigation thus reducing pumping hours by 40% on average during spring, summer and autumn and 33% during winter. Irrigation supplies to vegetables were also cut on average by 28.5% among interviewed farmers. Because of reduced irrigation hours, diesel consumption went down by 75.5, 78 and 73% during summer, autumn and winter seasons, respectively.

Contrary to Wadi Zabid, in Wadi Hadramout alfalfa was given priority by farmers compared to vegetables due to its better market outlets and lower cost of establishment. As a matter of fact, more than two-thirds of the farmers interviewed for this study ceased vegetable cultivation during 2011 and reduced pumping hours more drastically than for fodder. The reduction of pumping hours for alfalfa was 19, 28, 32, and 17% in spring, summer, autumn, and winter, respectively, which was only half the reduction in Wadi Zabid. The different responses of farmers may be attributed to the lack of alternative fodder crops to alfalfa in Wadi Hadramout. On average, considering all crops, pumping hours were curbed by 45% during summer. While pumping hours for fodder irrigation were reduced less in Wadi Hadramout than in Wadi Zabid, the overall reduction in diesel consumption for all crops was similar in the two regions: 79 and 75% for the summer and autumn season, respectively, in Wadi Hadramout, and 76 and 78% for the same seasons in Wadi Zabid. A strategy adopted by some farmers in Wadi Hadramout was to replace diesel with kerosene mixed with engine oil (in the ratio of 3 l kerosene: 20 l engine oil) for fuelling diesel engines. Subsequently, the demand of kerosene hiked and its price reached YER125/l. In addition, liquefied natural gas (LNG) was used for fuelling diesel engines, but this option was less desirable because of the risk of engine cracks. The use of kerosene fuel mixed with engine oil explains why reductions in pumping hours and diesel consumption are not in a 1:1 relation, with the latter being much higher than the former.

Figure 8. Variations of pump operating hours reported in five farms in Wadi Zabid (F1 through F5) in different seasons during 2010 and 2011.



Reduced irrigation supplies resulted in significant yield losses for farmers in the different regions. Vegetables were the most affected since they need irrigation every week, followed by fruit crops, which require irrigation at 15 day intervals. Qat can tolerate drought and usually was irrigated every 25 days. Farmers in the Jahran Plains in the Dhamar governorate, main suppliers of fruits and vegetables to the capital Sana'a and lead producers of tomatoes and potatoes in Yemen, reported yield losses of 40-60%. Moreover, their irrigated area shrank by 30-50%. In Sa'dah, where crop production is largely based on groundwater irrigation, interviewed farmers claimed average yield losses of 40% for vegetables and of 50, 20, and 33% for main fruit crops such as pomegranate, grapes, and apples, respectively.

The greater part of fodder produced in a farm is used to feed the livestock owned by the farmer himself. Wadi Zabid farmers considered livestock as the backbone of life for their families because of its multiple benefits: milk and milk products, meat and leather or cash income by selling the animals. In Wadi Zabid, lower irrigation supplies meant, on average, 60% yield losses for alfalfa and 50% for vegetables. Due to fodder shortages, many poorer farmers whose livelihoods depend on fodder and livestock were forced to sell their own livestock and this could be one of the most negative consequences on small farmers, particularly in Tihama and Wadi Zabid, and the livestock production sector in Yemen in general. In the Northern Tihama Plain, poorer farmers could cultivate only one-fourth of their land. Many of them sold part of their livestock to pay for diesel and produce fodder for the remaining livestock. Crop yields were significantly lower due to reduced number of irrigations and several fruit tree plantations (mangoes, lemons, figs) dried out. Initially, farmers reduced their farm area to cope with diesel shortages, only to discover, after the harvest, that there was no market for their products or that prices were lower than expected. As a result, they could not recover investment in the crop and were not able to raise new crops in the following crop season. Wealthier farmers having access to other income sources than agriculture could purchase enough diesel to secure a production that would enable them to recover their investment costs.

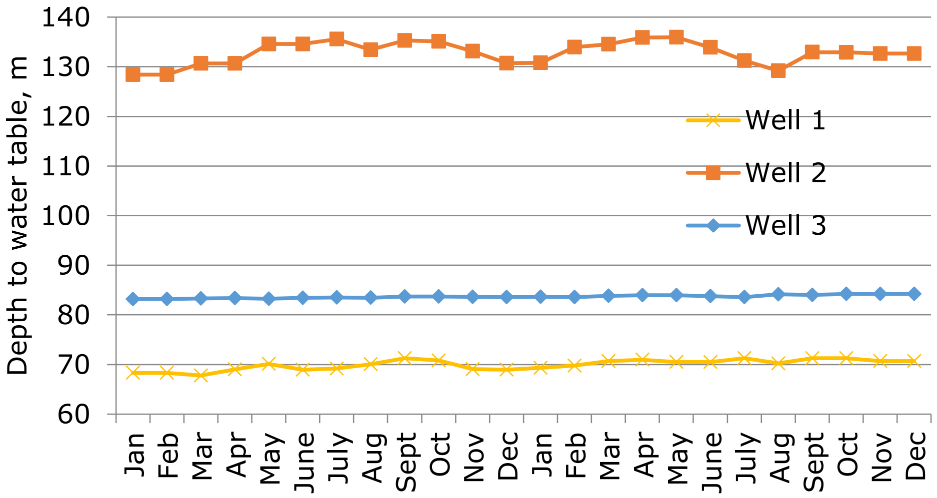
Qat was not as affected by the diesel crisis as other crops. Being more tolerant to water stress, even when water supplies were less than optimal, its quality was not substantially altered. As a result, prices of qat were not disturbed and their normal levels were maintained during all seasons. In Rada'a for instance, where qat is considered the prime irrigated crop, surveyed farmers cut pumping hours by half (from 20 to 10 hours/day) without major consequences on yields. In Sa'dah, the number of irrigations for qat were reduced from three to two during spring, from four to two during summer, and from four to only one irrigation during autumn and winter seasons. Contrary to Rada'a, this caused a yield reduction by 55% during spring, 30% during summer and autumn and 40% during winter seasons. Similarly, interviewed farmers in Bani Hoshaish area (Sana'a Basin) reported a reduction in qat productivity by 20% during spring and by 35% during summer and autumn seasons, due to reduced pumping hours by 37% during spring and summer seasons and by 33% during the autumn season.

An interesting case of farmers' reactions to diesel shortages was that observed in Bani Hoshaish, located in the eastern side of the Sana'a Basin. Here, grapes are almost the sole crop grown because qat cultivation, except in a few areas with micro-climates, is hindered by low temperatures and frost formation occurring in open valleys. The cultivation of grapes along the wadis is based on the conjunctive use of flood and groundwater roughly in 1:1 ratio relation. Because of the availability of floodwater, grape fields were not as severely affected, despite the reduction of pumping hours by 29% during spring, 42% during summer and 40% during autumn relative to pre-crisis levels. Irrigation of qat ceased altogether, given the higher profitability of grapes in this region.

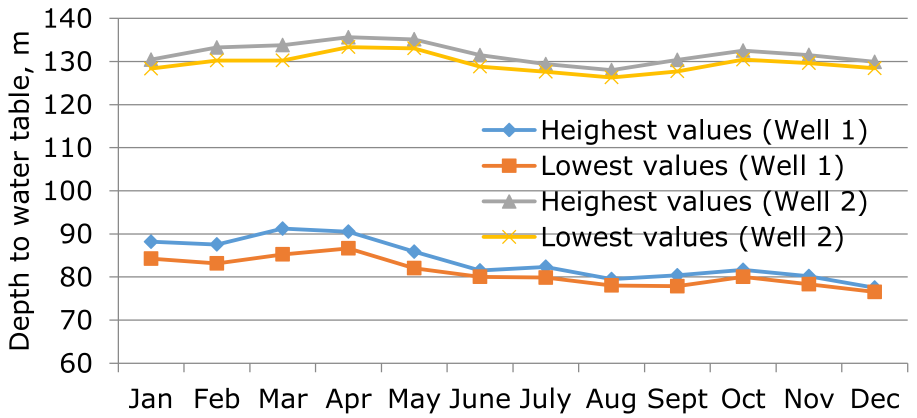
Impact of the diesel crisis on groundwater levels

The diesel crisis had a considerable impact on groundwater withdrawals and fluctuations in groundwater table. This is exemplified by records of measurements of groundwater table depth at three tube wells, which were monitored by the NWRA Branch in Dhamar during 2010 and 2011. These records reveal that the rate of groundwater depletion in the second half of 2011 was slowed down compared to 2010 (Figure 9a). Between January 2010 and March 2011, the water table depths of well 1, well 2, and well 3 increased by 2.34, 6.14 and 0.66 metres (m), respectively, indicating continued groundwater depletion. However, from April 2011 to December 2011 the water table depths in well 1 and well 2 were recovered by 0.29 and 3.24 m, respectively, while the water table depth in the third well continued to increase but at a slower rate. Similar trends of slowed depletion or even recovery of water table were observed in the data obtained from the Groundwater and Soil Conservation Project. Time series of groundwater level depths of two wells located in Dhamar area (Figure 9b) show that the monthly average highest depth decreased from 91 m in March 2011 to 78 m in December 2011 in one of the wells, while the depth decreased from 134 to 130 m in the other well for the same period. In the Northern Tihama Plain, surveyed farms reported no additional pipes were added into their wells in 2011 since the water table was stable.

Figure 9. Variations of depth to water table in tube wells located in Dhamar area from (a) January, 2010 to December, 2011, NWRA data (b) and from January, 2010 to December, 2010, GSCP data.



(a)



(b)

Impact of diesel shortage on wholesale prices of vegetables and fruits

Initially, it was assumed that the price of irrigated crops would give an indication of the decreased production and supply of the crops and therefore the decreased groundwater withdrawals. In a normal situation, a strong inter-governorate trade in agricultural products prevails, so that the prices of crops were governed by supply-demand relationships at the national level. However, the surveys of wholesale prices of vegetables and fruits conducted both in the Dhamar area (Table 3) and in Wadi Hadramout (Figure 10), revealed that the supply-demand relationships at the local level mainly governed the price of products. For a given region, large fluctuations in prices were observed for products, which are mainly produced for marketing outside the region and for imported products from other regions. The reason behind diverging trends in prices for different crops is the disruption in the market chain because of the surging of diesel prices and hikes in transport costs, up to 3-4 times. Farmers were forced to sell their products in the same region at low prices compared to previous years.

Inter-governorate trade of produces declined significantly because transport was reduced to minimum levels. As a result, produce piled at the farms and the prices fell sharply.

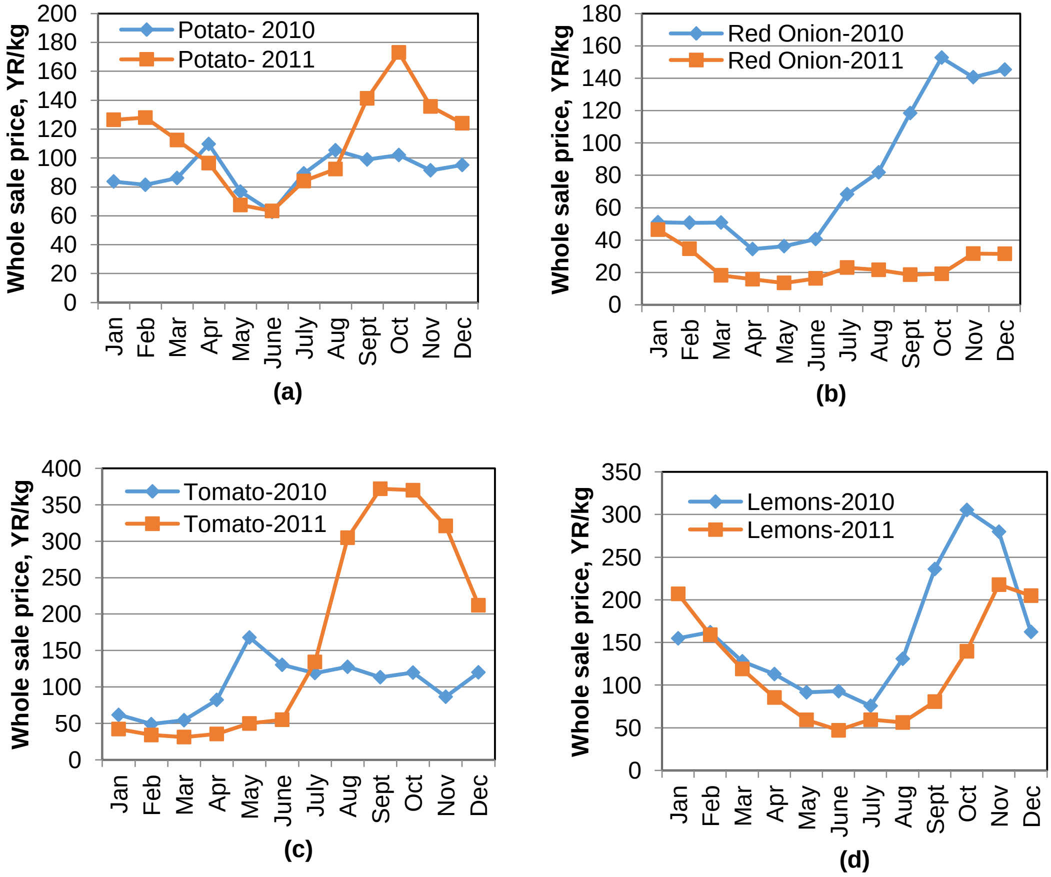
Table 3 indicates price changes of a few main crops grown in the Dhamar area. The low price column refers to the abundance period, i.e. crop season in the area, while the high prices are for the off-season prices. The price of tomatoes decreased by 20% in the crop season, but increased almost threefold during the off-season. So did the price for potatoes: A basket obtained a cost of YER1000 in the crop season compared to YER2050 in the preceding season.

Table 3. Average wholesale prices of vegetables and fruits in the Dhamar area before and during diesel shortage.

	Price before diesel crisis (YER/20-kg basket)		Price during diesel crisis (YER/20-kg basket)		% change in price during diesel crisis relative to pre-crisis	
	Low price	High price	Low price	High price	Low price	High price
Tomatoes	750	2450	600	7000	-20	186
Potatoes	2050	2700	1000	2600	-51	-4
Onions	1500	2500	400	2500	-73	0
Bananas	2250	2750	2400	4000	7	45
Muskmelons	2000	2750	1500	4000	-25	45
Oranges	2250	4250	2500	3000	11	-29
Grapes	2500	4500	3000	4000	20	-11
Mangoes	3500	4450	1200	5000	-66	12

As has been observed in other regions, also the marketing chain in Wadi Hadramout has been affected by the diesel crisis in various ways. First, the supply of vegetable and fruits produced in the area to the local market was highly reduced as a consequence of decreased irrigated land and deficit irrigation leading to loss of production. This was also observed in Wadi Zabid, where a reduction in the number of irrigations of 28.5% for vegetables resulted in a decline in productivity of 50% and an increase in prices by 25%. Second, the price of imported products, when available, was extremely high due to the increased transport costs. The average price of potatoes and tomatoes, both imported from other regions, increased from YER90 and YER103/kg in 2010 to YER112 and YER163/kg in 2011, respectively as shown in Figures 10a and 10c. Third, due to interrupted transport of locally produced crops to other regions, the prices of these products fell sharply. In Wadi Hadramout, red onions and tomatoes count as main vegetables, and dates and lemons as main fruits grown by farmers for income generation. Most of the production is marketed outside Wadi Hadramout. The average price of red onions and lemons decreased from YER81 and YER161/kg in 2010 to YER24 and YER120/kg in 2011, respectively, as shown Figures 10b and 10d. On average, onion farmers lost 70% of their income due to the fall of onion prices in 2011. The variation of wholesale prices of these four crops during 2010 and 2011 is shown in Figure 10. The large price variations of red onions were explained by the intensified production of this crop in Wadi Hadramout and subsequent piling up of huge quantities as stock. Similar cases were observed in Sa'dah where farmers incurred both productivity and income losses: a decline of 40% in yields was also associated with a loss of income due to a substantial decrease in market prices, which amounted to 80% for some vegetables and fruits.

Figure 10. Price variations of four main vegetable crops at Seiyoun (Wadi Hadramout) wholesale market during 2010 and 2011.



DISCUSSION AND CONCLUSIONS

The fuel subsidy dominated political and economic discussions in Yemen for the last two decades and its removal is regarded as highly sensitive. Besides being a major incentive for rampant groundwater use, it also serves many other functions (Hellegers et al., 2011), and affects so many other sectors of the Yemeni economy that it is hard to disentangle it. Perhaps in no other country in the world is the water-energy-food nexus, or, better stated, the energy-water nexus so obvious than in Yemen. Energy subsidy has triggered intensive groundwater development, which has boosted agricultural intensification and the shift to water-needy cash crops. In turn, dropping groundwater tables has rendered groundwater pumping increasingly energy-intensive and thus elitist. Menaces of increasing diesel prices unleashed diesel crises and social unrest in the past. The political crisis of 2011 and the resulting diesel crisis brought the diesel subsidy once again to the forefront of social and political attention. The diesel crisis of 2011 manifested in terms of shortage of unprecedented duration, coupled, for the first time, with extremely high prices. Similarly, a complete removal of the diesel subsidy was perceived as a 'diesel crisis' and was the spark that ignited the latest political turmoil in September 2014. Still, the diesel subsidy is an unsustainable burden on the government's budget, and a major contributing factor to Yemen's drying out.

Few lessons and conclusions can be drawn based on the results of this rapid assessment of the impacts of diesel crises, which are as follows:

1. A high diesel price promotes water efficiency in agriculture

It has been postulated that if diesel prices are increased farmers will opt for modern irrigation systems to reduce water pumping costs. However, farmers have shown that they can improve water efficiency using other quick tools as well. Farmers abandoned or shrank areas under irrigated cereals and fodder, reduced irrigation times and practised deficit irrigation, especially for qat which is a drought- tolerant tree. Although productivity and product quality of vegetables and fruits were reduced translating to losses for the farmers, they will choose less groundwater pumping and better water use strategies if the diesel cost is more than the marginal income. It is well known that irrigation practices among Yemeni farmers are very inefficient. Many crops including qat are irrigated by basin irrigation where water is used more than required. The irrigation efficiencies of surface irrigation systems which use groundwater are as low as 35 to 40%. The irrigation efficiency may be as high as 75 to 80% by improving irrigation practices and introducing modern irrigation systems (World Bank, 2010; MAI, 2014).

2. The impacts of high diesel prices and diesel shortage were highest on poorer farmers. especially in the Tihama Plains, whose farming systems are based on fodder for livestock and vegetables

Poor farmers have no cash savings to pay for the increases in diesel price. Farmers can tolerate doubling the price of diesel, but they cannot afford to buy it at 4-10 times its price. Usually, small farmers maintain livestock to gain additional minor income through selling milk and animals. Many poor farmers have found no option but to sell part of their livestock to buy diesel to sustain irrigation of farm trees and fodder. It is also worth mentioning that farm trees grown in hot and dry areas have much larger water requirements and have less capability to tolerate drought.

3. Only those farmers who can absorb increases in diesel prices, essentially due to high return cost ratios, higher drought tolerance, stable prices (qat), and access to alternative sources of water such as floodwater (grapes), can cope with the diesel crisis

It is well known that return cost ratios for some cash crops such as qat, vegetables and fruits is high. Farmers were able to tolerate pumping cost increases as far as their produce was payable. The case of qat is a good example where qat price went up and, at the same time, farmers water-stressed the qat a bit more thus reducing pumping costs. This applies to other marketable cash crops with high returns to water. The value of water and the unit costs of pumping water for crops, like grapes, tomatoes, potatoes and mangoes will almost break even under a 65% reduction in output prices. A reduction of about 80% in the output price of qat is required to significantly affect its profitability (Hellegers et al., 2011). The cost of water pumping will trigger farmers to substitute crops with low returns to water by crops with high returns to water.

Since returns to water vary a lot among crops and basins, a change in the costs of water may affect the profitability of some crops and some basins more than others. Changes to national incentives (e.g. increasing the price of diesel) would make, for instance, irrigation unviable in Wadi Hadramaut before impacting significantly on demand in Sana’a or Taiz. The danger of increasing the price of water is that farmers will convert to qat production on a large scale because the costs of water for qat are substantially below the value of water (Hellegers et al., 2011). This will trigger groundwater extraction even further (as actual irrigation water use of qat is above the average). The increases in costs required to impact on the profitability of qat will make other irrigated crops non-viable. In other words, incentives that decrease the profitability of irrigation at the farm level can trigger farmers to use water more productively, but are not the basis for bringing about a balance between demand and sustainable supply.

4. Diesel crises and breakdown of market chain of agricultural products have a combined effect on groundwater pumping

An assessment of the effects of diesel crises on groundwater pumping cannot be accurate and straightforward because diesel crises were accompanied with the breakdown of the normal market chain of locally produced crops due to the deteriorated security situation. Farmers suffer big losses not only because of high diesel prices but also because of the disturbance of the marketing process and suspension of intra-governorates transport due to sharp increases in transport costs and security risks.

5. Will diesel subsidies enhance inequity in income and wealth distribution among individuals and governorates?

No doubt everybody is benefiting from diesel subsidies. However, groundwater as an economic resource can be accessed only by well-off farmers. Yet, the same group of farmers is benefiting from diesel subsidies. Hence, diesel subsidies exaggerate inequity both in terms of access to groundwater and share of subsidised money. Although the majority of the population is classified as poor, the share of subsidised money eventually gained by this section is only 23% of the total amount. Qat farmers and areas growing qat achieve high incomes and low poverty rates compared to the farmers in other areas. On the other hand, diesel smugglers capture a lot of money, which was essentially public money paid in the form of fuel subsidies.

While diesel subsidies are unequally distributed and are distorted towards well-off farmers, the higher prices of diesel could further exaggerate another type of inequity, i.e. the opportunity inequity. Higher diesel prices will affect the profitability of many crops, especially those grown by poorer farmers such as vegetables and fodder which have fewer profit margins. The poorer farmers will have fewer opportunities to compete with well-off farmers because their farm produces will be more susceptible to changes in market prices due to their smaller margin of profit.

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