Water use licensing versus electricity policy reform to stop seawater intrusion

Zekri S.

in

Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.).
Water saving in Mediterranean agriculture and future research needs [Vol. 3]

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.III

2007
pages 121-132

WATER USE LICENSING VERSUS ELECTRICITY POLICY REFORM TO STOP SEAWATER INTRUSION

S. Zekri
Department of Agricultural Economics and Rural Studies
Sultan Qaboos University, Oman
Email: slim@squ.edu.om

SUMMARY - Groundwater over-abstraction is a major problem in Oman and mainly in the Batinah coastal area where it is accompanied by seawater intrusion. The Government tackled the problem since the beginning of the 1990's and implemented a set of recommendations based on the improvement of irrigation efficiency; the substitution of palm trees by winter only vegetable crops the use of appropriate tariff structures for non agricultural purposes and the re-use of treated waste water for municipal irrigation. However, fifteen years after the recommendations have been sketched the seawater intrusion in the Batinah aquifers is still advancing at an alarming pace. The current paper analyzes a set of scenarios based on water quotas, electricity pricing and annual electricity quotas. Results showed the cost of damages to the community if no active policy is implemented amount to 70.5 Million Rials. The solution consisting in the implementation of water property rights on tube wells only resulted in a Net Present Value (NPV) of 10 million Rials. Such a solution has the lowest NPV besides to the inequity it produces among farmers. Since water metering in dug wells is not possible then scenarios 3 and 4 consist in analyzing the control of groundwater pumping through energy prices and/or energy quotas instead of the water quota. The results are much better in terms of NPV as well as the equity among farmers. The electricity quota is the best and easiest solution to implement coupled with a complete subsidy removal of electricity price.

Key words: Oman, Groundwater management, water right, wells metering, energy price

INTRODUCTION

Several studies exist at international level regarding the over-abstraction of groundwater. The comparison of these studies shows that over-abstraction occurs independently of the climate, crop type, level of education of farmers, degree of social organization, farm size and irrigation system. For instance Masiyandima et al. (2002) studied the decline of water table in Dendron aquifer, South Africa. The rainfall is about 400 mm/year, mainly maize and vegetable crops are irrigated within 50 commercial farms. Farmers are organized in farmers' union as well as cooperatives. It is worth mentioning that farmers' union also voluntarily agreed on restricting irrigated area to 3% only out of the total cropped area. Despite the switch from furrow to sprinkler and computer scheduled irrigation systems the fall in water table has accelerated and ranged from 3.16 to 7.24 m/year during the period 1986-2000.

Groundwater over-abstraction is a major problem in Oman and mainly in the Batinah coastal area where it is accompanied by seawater intrusion. Groundwater monitoring in Oman dates back to the 1980's. A piezometer network was established in order to monitor changes in groundwater storage, seawater intrusion in coastal areas as well as pollution (Al Khatri, 2006). The agricultural sector uses more than 93% of the groundwater and the main agricultural area in Oman is situated in the Batinah region. More than 53% of the agricultural cropped area is situated in the Batinah coastal area where farming is exclusively based on groundwater pumping (MAF, 2006). Even though irrigation is considered a traditional activity in the Batinah, a rapid expansion of the irrigated area took place in the mid seventies, due to the introduction of diesel pumps. During the early 1970's total groundwater abstraction in the Batinah region was estimated to only 34 Mm^3 per year (MRMEWR, 2005). During the eighties the government implemented a land distribution program of small and large farms, and introduced electricity to rural areas which caused the groundwater deficit (MAF, 1993). Groundwater over-abstraction was clearly identified since the beginning of the nineties. Actually, the National

Water Resources Master Plan (NWRMP, 1991) called for a reduction of 215 Million m^3 of water pumping nation wide. Among the recommendations of the NWRMP to reach such a reduction are:

- the improvement of irrigation efficiency through the introduction of modern irrigation systems
- the substitution of palm trees by winter only vegetable crops
- the use of appropriate tariff structures for non agricultural purposes
- re-use of treated waste water for municipal irrigation

Fifteen years after the NWRMP has been sketched the seawater intrusion in the Batinah aquifers is still advancing as the recommendations have been only partially implemented. In fact, according to the 2004-05 agricultural census only 28% of the cropped area is under modern irrigation systems despite the up to 75% subsidy on irrigation equipment's cost. The area dedicated to palm trees has not been reduced when we compare the 1992-93 and 2004-05 census. On the other hand the area of vegetable crops has drastically increased. Not only the vegetable crop area has increased but the introduction of drip irrigation made it possible to grow summer vegetables leading to more stress on the groundwater and a lower economic efficiency. As for the pricing of groundwater for industrial and commercial uses a study was launched by the Ministry of Regional Municipalities, Environment and Water Resources but so far it has not been implemented (Al Suleimani and Al Wohaibi, 2006). Finally, the reuse of treated wastewater for landscaping is going on but more fresh water is also being pumped from the aquifer due to the extension of the irrigated area for beautification.

Besides to the above measures and since 1985 the Ministry of Regional Municipalities Environment and Water Resources (MRMEWR) has built 15 recharge dams in the Batinah region with a total storage capacity of 41.5 Mm^3/year. Between 1990 and 2005 more than 600 Mm^3 of water was collected in these dams. Assuming an infiltration rate of 75% of the water quantity arriving at dams (Al-Ajmi and Abdel Rahman, 2001) the aquifers' recharge is thus estimated to 450 Mm^3 with an average of 28 Mm^3 per year which is still far bellow the groundwater deficit of 177 Mm^3 per year. However, relying on groundwater supply augmentation is not a real option in an arid environment where aquifer recharge is limited by sheer physical scarcity of water regardless of the cost of recharge.

Despite the different technical and supply augmentation measures implemented the seawater intrusion in the Batinah region and the consequent water quality degradation is alarming more than ever before. Both the agricultural sector and the domestic water users are severely affected. Consequently, the Government is heavily investing in water desalination and water transportation for several areas affected by the salinity problem to service domestic users. The total cost of infrastructure for water conveyance is fully paid by the government in addition to the subsidization of the desalinated water. Besides to the high cost incurred by the Government, domestic water users are sheltered from the problem and will not push for a sustainable solution on groundwater over-exploitation.

METHODOLOGY

For economists the major cause of groundwater over-abstraction is the inappropriate property right regime: an open access type characterized by the absence of exclusion. The result is that groundwater users maximize their profit through maximizing groundwater pumping given that they have little confidence that other users will collectively limit groundwater pumping to a safe yield. Howe (2002) calls attention to the existence of three types of negative externalities in groundwater use due to the open access status of the resource; these are:

- contemporary pumping externalities which result in increasing the pumping costs by lowering the water tables
- inter-temporal externalities resulting from the change in groundwater stock that affects conditions of water availability in the future
- quality externalities as a result of seawater intrusion in coastal areas

Koundouri (2004) in a review paper regarding groundwater management stresses the fact that, according to existing economic results on several aquifers, competitive extraction is no different than optimal central control on groundwater in the absence of pollution and consideration of high discount rates. This led us to focus exclusively on the Batinah region where groundwater over-abstraction is accompanied by quality degradation due to seawater intrusion. In fact, in the interior regions of Oman over-abstraction of groundwater led to lowering the water table and in extreme cases to wells dryness. In such cases the public intervention is very costly compared to the expected benefits of establishing water quotas and well metering because it is a strict matter of wealth distribution; what is lost by a farmer is gained by another and given the absence of irreversibilities there is little impact on future generations. In other terms, when current farmers find it non profitable to continue pumping and after a certain period of time the aquifers could be replenished and pumping could restart again.

Two recent studies are explored regarding groundwater management in the Middle East region. The first one concerns Bahrain and the second one concerns Jordan. Zubari (2006) considers groundwater management options in Bahrain. The water demand management is discarded from the scenarios considered based on the fact that demand management is politically costly and did not work in the past. Instead, supply augmentation is considered in two of the three scenarios via desalination. Scenario comparison has been undertaken based on water balance instead of monetary evaluation. The financial burden is certainly huge, and such solutions would have never been possible to consider if it was not for the raise of oil prices since 2005. The author does not consider the sustainability issue into account, because it will be enough that oil prices fall down again and then insuring operation and maintenance of the desalination plants will be problematic. Besides, the intergenerational equity principal is not considered neither since oil revenues are considered to be the right of current generation. No real thinking about the consequences on future generations after oil depletion nor the right of future generations on oil returns is taken into account. As explained above supply augmentation scenarios are not considered in this study due to the fact that they weight too much in the public budget and will not ensure groundwater protection from over-pumping.

The recent adoption of the Jordanian authorities of wells metering and quotas allocation is very enlightening in relation to groundwater management. The adoption of that approach is explained by the severity of water scarcity, the strong capacity of the government to enforce regulations as well as the small number of wells monitored which is around 2,500 countrywide (World Bank, 2004, chapter 2) besides to the fact that 25.3% of the wells are used for municipal and industrial uses. On the other hand and considering stakeholders participation it is worth mentioning that water issues are debated for in all political institutions and farmers' union representatives are closely consulted for all questions related to the management of the groundwater. Chebaane et al (2004) summarizes the options considered to reduce over-pumping in Jordan and the way farmers has been approached. Five options have been considered in the study. These are:

- Option 1: On farm water management and irrigation advisory board creation: It consists of assisting farmers to enhance introduce more efficient irrigation technologies via an irrigation advisory board.
- Option 2: Buy-out of wells: it consists of the Government buying-out the irrigation wells and/or the irrigated land and closing them down as a way to reduce over-pumping.
- Option 3: The enforcement of an abstraction limit and/or reduction of the cropped area: it consists of implementing a water quota of 100,000 m^3/year/well in order to reduce the over-pumping of the agricultural sector by 55%.
- Option 4: Exchange of groundwater with treated wastewater: it consists of substituting 10 Mm^3/year of groundwater by wastewater in the agricultural sector.
- Option 5: Municipal and industrial pumping reduction: it consists of studying the impact of improving water use efficiency and obtaining alternative sources of supply.

It is to be observed that option 5 is more a supply augmentation option than a demand management one. Option 1 is not a demand option neither since it has been proven that introducing more efficient irrigation technologies do not always reduce overall water use but could result in higher productivity and returns (Huffaker and Whittlesey, 2003). This judgment is even more accurate in desertic climates where evaporation is extremely high and where farm land availability makes it possible to extend the irrigated area rather than keeping in the aquifer the quantity of water saved. Although Peterson and Ding (2005) argue that efficient irrigation systems may save water and plead for subsidizing irrigation systems, in their model they assumed that the cropped land is not allowed to be extended. It is obvious that under such a limit on cropped land coupled with a more efficient irrigation system the result is a reduction of groundwater over-pumping. The buying out of wells and/or cropped land, option 2, is one option that might lead to groundwater pumping reduction in the short term, however in the long run, and if no limit on extraction is imposed, the saved water will be pumped by the active farmers given the existence of idle land. In regard to option 4 which pretends to substitute groundwater by treated wastewater, the major concern in the case of Oman, and in most countries, is that treated wastewater is much more costly than pumped groundwater. Currently Oman Wastewater Company is planning to sell the treated wastewater at 0.110 Rials/m^3 (0.29 US$/$m^3$). Given the high price it is very much unlikely that farmers will shift from groundwater pumping to a lesser water quality at a higher price. Although Chebaane et al. (2004) justify such an option by the fact that cost of treated wastewater is less than the present value opportunity cost of groundwater, irrigation could no longer be sustained based on subsidies and wealth transfer from public budget at the expense of other sectors and future generations. Cost recovery is a must for any sustainable agricultural activity.

Water scarcity in Oman is more severe than is the case in Jordan; however the number of wells is too high compared to Jordan. Since several solutions have already been tried in Oman and still facing the fatal advancing seawater intrusion, implementing groundwater property rights and monitoring through wells metering should be evaluated as one potential solution to the problem. Government monitoring capacity should be built over time and should not be considered as a prerequisite to the development of a groundwater right system. However, one of the major problems faced in Oman is the high number of wells. Actually in the Batinah region alone more than 100,000 wells are censed out of which only 5% are tube wells. Implementing a water right system in dug wells is not physically possible as farmers can easily add and remove a non metered pump. The water right system is thus only physically possible in the case of tube wells. Experiences in countries, such as Mexico and India faced with over-pumping of groundwater and a large number of wells showed that the reduction of over-pumping could be achieved through a better pricing of electricity power. An increase in electricity price leads to an increase in the marginal cost of irrigation water. Consequently, linking groundwater extraction to electricity prices in order to give incentives to farmers to use the water resource in a more efficient way is an approach that will be considered due to the impossibility of controlling the water pumping from dug wells. Actually Mexico is going beyond just electricity price reform by implementing an annual energy limit per well according to well depth and the annual water quota (Scott and Shah, 2004; Kumar, 2005). Finally, encouraging the adoption of modern irrigation systems where capping of extraction is possible will be explored. The objective of subsidizing the modern irrigation systems is to offset the economic losses that farmers will incur in as a consequence of restrictive quota compared to the current situation.

The method used in this paper is cost-benefit analysis Griffin (2006). In what follows costs and benefits are identified and the methods of estimation are highlighted. The paper is based on the assumption of implementing a water right system, precisely water quotas and extraction control through tube wells metering coupled with an electricity price reform, an annual energy limit and a more active policy for modern irrigation systems subsidization after capping either electricity of water.

The expected benefits refer to:

1. Stopping the water table decline which will result in pumping energy cost savings;
2. Protecting the traditional irrigation systems of Aflaj (Zekri and Al-Marshudi, 2006) from drying up due to the over-abstraction.
3. Protection of groundwater quality from an increased salinization for current users both farmers and domestic users;
4. Protection of the aquifers for future uses from salinization in order to avoid the irreversibility phenomena;
5. Removal of the electricity subsidy;

The costs are mainly related to:

6. The investment and operating costs of groundwater pumping control and installation of water meters on tube wells;

7. Financial losses of farmers due to the introduction of restrictive water quota compared to existing pumping;

8. The cost of creation of the appropriate institutions to monitor the reform and the implementation of a participatory approach and extension program to stakeholders.

9. The cost of subsidizing the modern irrigation systems subjected to water quotas or annual energy limit

CASE STUDY OF THE BATINAH REGION

Fall in water table: energy and deepening cost savings

According to (Al khatri, 2006) the fall in water table for the period 2002-2004 has reached up to 5 meters while in some wells the level of water has risen up probably due to the excessive salinization and farmers stopping pumping. On average the water table has fallen by 0.24 m/year considering all wells. However, it is more appropriate to discard those wells which salinity has increased and where pumping stopped. Thus, in what follows we will consider a fall of the water table of 0.34 m/year. According to Malik and Al-Zubaidi (2006) the economic cost of electricity is 0.02517 R.O/kWh. The extra energy cost is thus estimated based on comparison of costs of extractions at different depths and taking the marginal increment times the fall in water table annually. Besides to the extra energy cost farmers have to deepen their wells resulting in cost of deepening the wells and relocating the pumps.

Aflaj dry up.

The total number of Aflaj systems in Oman was estimated to 4,112 systems in 1996 (MRMEW, 2002). Currently only 3,000 Aflaj are still active in the whole country (MRMEWR, 2005) besides to the fact that for many of the active aflaj the volume of supply has decreased sensibly. The volume of water supplied by Aflaj was estimated to 459 Mm^3 according to Al Sarhani (2000). The master plan for the water sector estimates the volume of water supplied by Aflaj to 377 Mm^3 (MNE, 2003). Thus the reduced volume of supply during the period 1999-2003 is 82 Mm^3 or 4.4% annually. Data related to the Batinah's monitored aflaj shows that 14 Aflaj dried up between 1996 and 2006 with a corresponding 0.61% annual loss of water. This last figure is used in our estimation. Since water markets in Aflaj systems are active then the market price is the best indicator of the losses incurred by farmers. Zekri et al. (2006) estimated the 2003 average water price for a sample of Aflaj to 0.0365 R.O/m^3. Total loss to farmers using Aflaj is the unit market price times the volume of reduced water annually.

Quality degradation

Groundwater salinization is one of the most devastating problems facing Oman. Al Barwani and Helmi (2006) mentioned a saline interface of 12 km inland in the Barka area in Batinah up to 2005. During the period 2000-2005 around 2,714 ha of agricultural land was lost due to salinity increase which was clearly corroborated by the abandonment of 116 wells out of the 716 wells considered in the study. Forty seven percent of the wells had a salinity above 6.000 µS/cm in 2005. In Wadi Al Taw and Wadi Maawil the water suitable for domestic uses (salinity <2000 µS/cm) was reduced from 23 km^2 in 1991 to zero in 2000. Currently, in the area between Suwaiq and Barka the groundwater is no longer usable as a source for drinking purposes.

Farmers' losses

Farmers' losses due to salinity increase are of two types. The first type of loss is based on estimating the financial losses due to farming abandonment where groundwater became unsuitable for crops growing. The second type of losses is estimated based on yields decrease as a function of salinity increases. The tolerance of crops to salinity is based on the study of Hussain et al. (2006).

The financial loss on a per hectare basis is obtained through comparison of the profit obtained under different salinity conditions after farmers adjustment to salinity. Data was obtained in MWR (2000) and year 2006 prices were applied. To obtain the total future losses, areas under different quality conditions were projected based on Al Barwani and Helmi's results.

Domestic users' losses.

In response to groundwater salinity increase domestic users has shifted to buying water from service providers through tankers. Given a higher price of water domestic users buy smaller quantities than the ones they used to use from the groundwater. This surplus loss is not considered in this study due to lack of information regarding domestic water demand functions. The difference between the cost from groundwater and water tanks prices times the volume of water delivered by tanks is used as a measure of the financial loss incurred by domestic users. For the current and expected volumes serviced by tanks in the Batinah region we referred to the statistics from Ministry of Housing and Electricity (2005). The price of water serviced from groundwater is estimated at 0.264 R.O/m^3, while the prices of water delivered by tanks differ from one customer to another according to the house distance from the source of water. We considered an average of 1.057 R.O/m^3. Thus the difference in price is estimated at 0.793 R.O/m^3.

Irreversibility

The phenomenon of groundwater salinization is most likely irreversible in the Batinah region due to the existence of depressions in the aquifers. Even if we suppose there is a possibility that the phenomenon could be reversible it would take several decades of zero pumping to partly recover the quality of the aquifer (Kacimov, 2006, personal communication). Kacimov and Sherif, (2006) stated clearly that "*… no other water resource can fully substitute the groundwater resource in the foreseen future, especially in the agricultural sector. Therefore every possible effort should be made to protect and sustain the groundwater resource".* Consequently, it is more realistic to suppose irreversibility than resilience. In this case, there is no possibility to replace the aquifer as storage reservoirs. Feasible dams in the Batinah have already been constructed, besides to the fact that dams in Oman have a relative short life due to siltation. Usually in desertic climates such as in Oman dams are built to recharge the aquifers which are used as storage reservoirs to avoid the evaporation. Since the aquifers are salinized they could no longer be used as receptacles of fresh water and thus the only alternative is to desalinate water. Consequently the damage caused by current water users to future generation is estimated as the aquifer's safe yield times the opportunity cost of water. The cost of desalination for drinking purposes is 0.5 rials/m3 as estimated by Al-Ajmi and Abdel Rahman (2001). The irreversibility cost will be taken into account during the two last years of the project only.

Electricity subsidy removal

Monitoring of all wells is a must to ensure a total reduction of groundwater over-pumping. Otherwise, if only the tube wells are monitored then the water saved will be much likely pumped by dug wells owners who are not subject to quota. Since the limiting resource in the desertic climate is water, then it should be expected that farmers will pump the water up to their well capacity as far as the agricultural land is available and under used. Consequently if dug wells will not be monitored there will be no water saving and no reduction of the damages of over-pumping. Given that the dug wells could not be monitored through a water quota system due to their large number then the surrogate method is to increase the electricity price. The objective is to send the right signals to farmers that groundwater is scarce, and press on them to reduce the quantities pumped through higher electricity rates. More than 74% of the area is irrigated by wells using electricity as a source of energy. The current electricity prices in the agricultural sector are of a block tariff type. The first block is of 0.01 Rials/kWh for consumption under 7000 kW and 0.02 Rials/kWh for consumption above 7000 kW. The long run marginal cost (LRMC) was recently estimated to 0.02517 Rials/kWh. Electricity is billed monthly in Oman. Given an estimated cost of groundwater pumping of 0.0019 Rials/m^3 considering a well depth of 35 meters and a total efficiency of pump of 50%, and given an average water consumption per ha of 20,765 m3/ha (Al Suleimani and Al Wohaibi, 2006) then all farms having less than 19 ha are benefiting from the lowest electricity rate of 0.01 Rials/kWh. According to the 2004-05 census more than 87% of the farms in the Batinah are less than 19 ha. Thus the percentage of the area that could be affected by electricity price increase is (74%*87%) 64% of the current cropped area if a single rate of electricity of 0.02 Rials/kWh were used. The total cropped area falling under wells as a source of irrigation is estimated at 28,541 ha. In a second option we will explore the impact of total subsidy removal and pricing using the LRMC of 0.02517 Rials/kWh. To estimate the quantity of water to be potentially saved as a consequence of electricity price increase we will recur to water price elasticity. Zekri et al (2006) estimated the irrigation water demand functions for the traditional systems in Oman based on temporary water markets. Though the crop mix under the traditional irrigation system differ slightly than the crop mix irrigated through wells, the results obtained are the best available for this case study given that they are based on water market prices and reflect the Omani environmental and market conditions. The log-log functions estimated led to water price elasticities varying between -0.10 and -0.28 indicating that a 1% increase in water price leads to a decrease of 0.1% and 0.28% of water pumping respectively. An average elasticity of -0.19 will be used to estimate the potential volume of water that could be saved as a consequence of electricity price rise. The subsidy removal is an economic benefit that will be estimated as the differential between the current electricity price and the future price times the volume of water.

Water quota: Investment, operating and maintenance costs of the water meters

The solution to be implemented to reduce the groundwater over-pumping and seawater intrusion is based on the implementation of water property rights through water quotas and wells metering and control of pumping. In this paper we consider the implementation of quotas only in tube-wells. Water metering in dug wells will not be considered for two reasons. First, surveillance of water pumping from dug wells is extremely difficult. Farmers can at any time easily install/remove a non metered water pump which could be used to pump unauthorized water. Second, it is non feasible economically to install meters in dug wells given that there is around 100,000 dug wells in the Batinah area which cost of investment, control and enforcement of quotas is prohibitive. Consequently in what follows it is consider that the only wells where water capping could be enforced are the tube-wells which number is 5,053. From the NWRMP (2000) the amount of water over-pumped in the Batinah is estimated 177 Mm^3. We estimated current total water pumping from groundwater at 593 Mm^3/year. Thus the over-pumped water represents 30% of total pumped water and the safe yield is 415 Mm^3/year. The area covered by the tube wells is estimated at 7,734 ha according to the 2004-05 Census. Average groundwater pumping from the tube wells is 20,765 m^3/ha/year as mentioned in Al Suleimani and Al Wohaibi (2006). Thus, the total volume of water extracted from tube wells is 160 Mm^3 per year. The figures show clearly that it is economically and politically non feasible to reduce 177 Million m^3 from the water currently pumped from tube wells alone. Such a policy means the closing down of all the tube wells. Such a decision means simply closing down the new farms that have been promoted by the government during the last 2 decades. Consequently, the water quota for tube wells should be coupled with electricity subsidy removal and/or setting an annual energy limit or electricity quota. Otherwise, it is impossible to reduce the over-pumping of the groundwater.

The water quota should be based exclusively on the current net cropped area irrespective of cropping mix and crop type and not on a well basis. Quotas will be set equally among all aquifers in the Batinah area to ease enforcement.

The installation of water meters aims to control the pumped quantity from each one of the tube wells. Meters of 4 different brands were installed in wells in Batinah and their performances have been tested for 7 years (Al Suleimani and Al Wohaibi, 2006). For simplification only the brand with the highest technical performance is retained for the economic analysis in this paper. In most of the countries where wells metering have been implemented the cost of meter and its installation are at the expense of the wells' owners (MWI, 2002; Sanger, 2003; Cummings et al. 2005; Cunneen, 2006). In this paper we will explore the payment and maintenance of the meters in installments which will be called license fee. A workshop for maintenance and control of the meters is planned for with the necessary equipments, cars and technicians. A special unit should also be created to monitor the meters, send the bills to farmers every six months, one at the end of the winter season and the other at the end of the summer season. The objective of sending the bills is to inform every farmer about the quantity he pumped and the remaining volume that could still be pumped under his license. Any pumping above the volume stipulated in the water quota should be charged at a dissuasive tariff to discourage farmers from over-pumping.

Cost of monitoring and participatory approach

Improving groundwater management requires getting users involved in formulation of general goals and in the management system. For the promotion of participatory aquifer management, it is important to consider the different roles of various actors in order to protect the public's interests, consider the equity issues and the needs of future generations, and insure improved water use efficiency and allocation. The government's roles include development of legislation after discussion with farmers' representatives, establishment of financing policy, acting as regulator and implementing extension programs for the policy change and enforcement of water quotas and the annual energy limit. To be effective the establishment and implementation of laws & regulations require the consensus of all the actors and mainly groundwater users. Campaigns for farmers' persuasion of the need of implementing a water quota system coupled with setting an annual energy limit per well should be deployed to change farmers' behavior from awareness about the problem into a willingness to participate in the effort to protect the aquifer. Currently the extension service in charge of irrigation water is under the responsibility of the Ministry of Agriculture and Fisheries. We consider that such an institution could implement the task of informing and involving farmers in the process with the support of 6 experts for a period of five years and the needed budget. The objective of this team is to discuss with farmers the different options available and show them experiences from other countries where water metering and energy limits are adopted.

Financial losses to farmers due to the introduction of a restrictive water quota and annual energy limit

Since the objective of implementing the water quota is to reduce over-pumping, then farmers will have to reduce their current pumping to a level that is considered safe which will prevent seawater intrusion. Current water pumping is estimated at 20,765 m^3/ha/year. The total volume of water that should be reduced is 177 Mm^3/year. This volume will be cut from tube wells and dug wells. The application of such a quota is going to considerably reduce the irrigated area and will have a negative impact on farmers' income. Some of the farms will not survive. Thus allowing farmers to trade their water quotas or the annual energy limit should be considered, so small farms that can not resist the water quota or annual energy limit could be able to sell or rent their quotas to other farms and getting a rent out of it.

Cost of subsidizing the modern irrigation systems

The objective of subsidizing the modern irrigation systems (MIS) is not to reduce over-pumping. It is meant here as a solution to compensate farmers based on tube wells from the losses incurred as a consequence of imposing a restrictive water quota. A survey implemented in the Batinah region showed that most farms are already using MIS partly and not on the whole irrigated area. The limitation is due to the fact that the budget allocated yearly at the Ministry of Agriculture to subsidize the MIS could not respond to all demands. Thus in what follow we will consider that such a limitation is removed and that the whole cropped area under tube well irrigation could be equipped with MIS.

Four scenarios will be considered in this paper and are as follows:

- Scenario 1: Business as usual, with no implementation of any control, surveillance or economic instruments. The objective of this scenario is to estimate the present value of the expected economic losses due to over-abstraction.
- Scenario 2: Implementation of a water right quota and control of extractions through the installation of water meters on the tube wells coupled with the consideration of a unique electricity price of 0.020 Rials/kWh instead of the two block tariffs currently in use.
- Scenario 3: Total removal of electricity subsidy and pricing at the LRMC of 0.02517 Rials/kWh, without installation of water meters on tubewells
- Scenario 4: Imposition of an annual energy limit for wells using electricity, irrigation systems subsidy and an electricity tariff of 0.02 R/kWh

Sensitivity analysis: Decreasing discount rate (Koundouri, 2004)

RESULTS

Continued over-abstraction of groundwater in the Batinah area will result in further deterioration of the water quality, additional fall in the water table, more aflaj dry up; more domestic water users relying on alternative drinking water sources and final irreversible destruction of the aquifer as a reservoir of fresh water. Scenario 1 is the “business as usual” scenario. Considering a 25 years period the present value of total losses is estimated at 70.5 Million Rials, considering an 8% discount rate. These losses are distributed as follows:

14 Million Rials losses due to salinization in the agricultural sector;

23.8 Million Rials increase in energy costs and wells deepening due to the progressive fall down of the water level in the over 100,000 wells in the Batinah

3.1 Million Rials losses due to aflaj dry up considering only the agricultural losses.

20.8 Million Rials losses to domestic water users who need to shift to other sources of fresh water

8.7 Million Rials of losses due to the irreversibility affecting the aquifer as a receptacle for fresh water

The abandoned of land is estimated to 5,995 ha besides to more than 5,000 ha that will be moderately affected by salinity. This will result in losses of 20,000 jobs 1/3 of them affecting expatriates from neighbor countries.

The results for scenario 2 to 4 are summarized in table 1. The highest net present value (NPV) is obtained for scenario 3 based on electricity pricing at the marginal cost of 0.02517 per kWh. In such a case the NPV is 41 Million Rials. Out of the 41 Million Rials, 14 Million Rials go as benefit to the government due to the subsidy removal. Land to be retired from irrigation is 4,902 ha based on dug well plus 1,585 based on tube wells. The present value of total government expenditures is estimated to 2 Million Rials which is more than offset by the subsidy removal. For Scenario 2 the NPV is the lowest with only 10 Million Rials. This scenario is based on the assumption of water metering on tube wells. Tube well owners will have to cut the water use by 65% which will result on reducing the cropped area by more than 50%. Besides, tube well owners will be submitted to an annual license fee of 80 Rials to cover the depreciation, maintenance and operating of the water meters. Dug well owners in scenario 2 will reduce their pumping by only 17% as a consequence of electricity price rise from 0.01 to 0.02 Rials/kWh. Total job losses in this scenario are estimated to 18,847 jobs. Finally Scenario 4 has a NPV of 33 million Rials and is based on the premise of imposing an annual energy limit. Such a limit is based on two block tariffs. The first block is 0.02 Rials/kWh and the second block will be a dissuasive price of 0.05 Rials/kWh. The annual energy limit is actually an energy quota which will be estimated based on current cropping area, the well depth and the water quota per ha of cropped land. The objective is to control groundwater pumping through energy quota instead of the water pumping and water quota. The advantage of scenario 4 is that the groundwater deficit reduction is evenly distributed among farmers owning dug wells and tube wells. The present value of Government expenditure is estimated to 5 Million Rials mainly going to a more active policy in subsidizing MIS. In this case, the financing of the MIS could be done by the return from electricity price subsidy removed. Farmers will not have to pay any annual license fee since monitoring will be insured by the electricity meters already in place. Scenario 4 is thus the most politically attractive since all farmers are treated equally. The increase in electricity price is not abusive, since the 0.02 Rials/kWh will be used and not the marginal price. There is no need to create any new institution to implement the project and control the meters. Farmers on he other hand could benefit from MIS subsidy to offset part of the losses generated by the electricity annual limit.

Table 1: Results of the three scenarios

	Scenario 2: Tube wells metering and electricity price increase from 0.01 to 0.02 R/kWh	Scenario 3: Electricity pricing at Marginal cost 0.02517 R/kWh	Scenario 4: Annual energy limit equally set for all wells no water meter plus MIS subsidy
Volume of water to be cut from dug wells in Mm3	72	103	125
Volume of water to be cut from dug wells in percentage	17%	24%	29%
Volume of water to be cut from tube wells in Mm3	105	53	52
Volume of water to be cut from tube wells in percentage	65%	33%	33%
Land retirement currently under dug wells irrigation in ha	3,953	4,902	5,402
Land retirement currently under tube wells irrigation in ha	3,790	1,585	1,585
Net present value in Million Rials	10	41	33
Present value of government expenditures on the project in Million Rials	5	2	5
Tube wells license fee (meters cost recovery plus operating & maintenance cost)	80	0	0
Present value of subsidy removal in Million Rials	9	14	9
Jobs losses	18,847	15,790	16,407

CONCLUSIONS AND RECOMMENDATIONS

Four scenarios have been analyzed to stop seawater intrusion in the Batinah. The business as usual scenario is developed to evaluate the potential damages if nothing is done. The present value of total damages is thus estimated to 70.8 Million Rials. This figure shows clearly the need a more active groundwater policy. Three scenarios have been drafted for this aim. Scenario 2 is based on water quotas on tube wells via the installation of water meters and issuance of licenses resulted in the lowest NPV and the highest jobs losses. Scenario 3 consists of a sharp increase in electricity price up to the current marginal cost of electricity. The reduction of over-pumping is almost equal among farmers though it affects more tube well owners than dug well owners since the former wells are deeper. However, scenario 3 will most likely be strongly opposed by farmers. It also implies an unwanted demand decrease for the electricity company. A compromise solution consists then in scenario 4. The implementation of an annual energy limit coupled with subsidy removal of electricity price will result in more acceptable results by farmers and more equitable distribution of the losses among farmers owning dug wells and tube wells.

Finally, the electricity subsidy should be completely removed in order to increase the cost of water pumping. A single block tariff of 0.02 Rials/kWh should be implemented to partially stop the seawater intrusion. Besides, electricity price increase alone will not help stop the over-pumping. There is a need to implement an electricity quota to insure a full protection of the aquifer from seawater intrusion. Implementing water meters will have a very high negative impact on tube well owners who will perceive this option as an inequitable solution. Most of farmers are quite aware of the salinization problem taking place. However few of them only showed willingness to accept an annual license fee payment. Thus raising awareness of farmers and providing them with detailed information regarding the different scenarios is a must to insure success of any groundwater future policy.

REFERENCES

Al-Ajmi, H.; Abdel Rahman, H. (2001). Water Management Intricacies in the Sultanate of Oman: The Augmenting-Conservation Conundrum. Water International, 26(1), pp 68-79.

Al Barwani, A.; Helmi, T. (2006). Seawater Intrusion in a Coastal Aquifer; A Case Study for the Area Between Seeb and Suwaiq, Sultanate of Oman. Agricultural and Marine Sciences, 11(SI). pp 55-69.

Al Khatri, A, M, H. (2006). Rationalization of groundwater monitoring network in South Al Batinah region, Oman. Master thesis. Sultan Qaboos University. Sultanate of Oman.

Al Sarhany, I. I. (2000). Water Resource in the Sultanate of Oman challenges and Opportunities. M.Sc. Thesis, Loughborough University, UK.

Al Suleimani, Z.K; Al Wohaibi, B.K. (2006). Water Metering Pilot Project: A case Study of Water Demand Management in the Sultanate of Oman. Agricultural and Marine Sciences, 11(SI). pp 71-76.

Ayers, R.S.; Westcot, D.W. (1995). Water quality for Agriculture. Irrigation and Drainage Paper 29. FAO. Rome.

Chebaane, M. El-Naser, H.; Fitch, J.; Hijazi, A.; Jabbarin, A. (2004). Participatory Groundwater Management in Jordan: development and Analysis of options. Hydrogeology Journal, Vol (12), pp 14-32.

Griffin, R.C. (2006). Water Resource Economics: The Analysis of Scarcity, Policies and Projects. The MIT Press. Cambridge, Massachusetts.

Huffaker, R.; Whittlesey, N. (2003). A Theoritical Analysis of Economic Incentive Policies Encouraging Agricultural Water Conservation. International Journal of Water Resources Development, 19, pp 37-53.

Hussain N.; Al Wehaibi, N.S.; Al Habsi, S.S.; Al Bakri, A. (2006). Hydro-economical localization of Oman agriculture. Proceedings of the International Conference on Economic Incentives and Water demand Management. Pp 188-197. Muscat, 18-22 March 2006. Oman.

Kacimov, A. R; Sherif, M.M. (2006). Modelling of groundwater in two selected coastal aquifers of UAE and Oman as a precursor for water resources management. Final report. United Arab Emirates university and Sultan Qaboos University. October 2006.

Kumar, D.M. (2005). Impact of electricity prices and volumetric water allocation on energy and groundwater demand management: Analysis from Western India. Energy policy 33(1), pp 39-51.

Koundouri, P. (2004). Current Issues in the Economics of Groundwater Resource management. Journal of Economic Surveys, Vol 18(5), pp 703-740.

MAF. (1993). South Batinah Integrated Study. Ministry of Agriculture & Fisheries. Directorate General of Agricultural research. Volume 3. First Edition

MAF. (2006). Agricultural Census 2004/2005. Ministry of Agriculture & Fisheries. Department of Statistics and Information. Sultanate of Oman.

Malik, A.S.; Al-Zubeidi, S. (2006). Electricity tariffs based on long-run marginal costs for central grid system of Oman. Energy 31 (2006) 1703–1714.

Masiyandima, M.; Van der Stoep, I.; Mwanasawani, T.; Pfupajena, S.C. (2002). Groundwater management strategies and their implications on irrigated agriculture: the case of Dendron aquifer in Northern Province, South Africa. Physics and Chemistry of the Earth 27 (2002) 935–940.

MRMEW. (2002). Aflaj in the Sultanate of Oman. International Printing Press, Sultanate of Oman. Ministry of Regional Municipalities, Environment and Water Resources.

MRMEWR, (2005). Water Resources in Oman. Ministry of Regional Municipalities, Environment and Water Resources. November 2005. Sultanate of Oman, page 60.

MNE, (2003). Master plan for the water sector. Volume 4-Annexes. Mott MacDonald & Company LLC. Ministry of National Economy. Sultanate of Oman.
MWR. (2000). National Water Resources Master Plan. Annex G – Agriculture. July 2000.Binnie & Partners and Arcadis Euroconsult. Minstry of Water Resources. Sultanate of Oman.
NWRMP. (1991). National Water Resources Master Plan. Ministry of Water Resources. Mott MacDonald International Limited & Watson Hawksley. December 1991.
Peterson, J.M.; Ding, Y. (2005). Economic Adjustment to Groundwater Depletion in the High Plains: Do Water-Saving Irrigation Systems Save Water? American Journal of Agricultural Economics, 87(1), pp 147-159.
World Bank, (2004). Water Resources Sector Strategy: Strategic Directions for World Bank Engagement. The World Bank. 88 pages.
MWI, (2002). By-Law 85/2002. Underground water Control By-Law. 13/08/2002. The Water Authority. The Ministry of Water and Irrigation. The Hashemite kingdom of Jordan.
Cummings R. G., Walker, M.B.; and Ackaramongkolrotn, K. (2005). Georgia's Agricultural Water Use Metering Program: Using Results To Benefit Farmers And The State
Water Policy Working Paper #2005-006. Georgia State University. Feb, 2005.
Sanger, M (2003). Water Metering in Texas.
www.texaswatermatters.org/ pdfs/articles/water_metering_in_texas.pdf -
Scott. C. A.; Shah. T. (2004). Groundwater Overdraft Reduction through Agricultural Energy Policy: Insights from India and Mexico. Water Resources Development Vol. 20, No. 2, 149–164, June 2004.
Cunneen, J. (2006). Metering in South East.
http://www.dwlbc.sa.gov.au/water/projects/meteringse.html#Metering_Newsletters
Zekri, S.; Kotagama, H.; Boughanmi, H. (2006). Temporary water Markets in Oman. Agricultural and Marine Sciences, 11(SI), pp 77-84.