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Improved on-farm participatory water management to reduce mining of groundwater in Yemen

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By

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ABSTRACT

Water shortage is the most critical issue facing the Middle East and North Africa (MENA) Region and is likely to be exacerbated in the future because of high population growth and continuing decline in the renewable resources resulting from climate change, pollution and overdraft of groundwater. Despite this alarming situation, water management still faces major drawbacks as the largest share is used for agricultural production under traditional farming practices and low on-farm water use efficiency, resulting in very low output per unit of water use and consequently low economic returns from investments. However, because of the scarcity and unreliability of precipitation in the region, the improvement of irrigated farming systems still presents a high potential in the region and will undoubtedly continue to attract investment in the future, in comparison with rainfed systems.

The present study is based on the outputs of several projects and sectoral studies, particularly a World Bank financed project aimed at introducing modern irrigation technological packages, in a participatory manner, under all major existing farming systems, as a measure to enhance water savings and improve farm income.

The study proves the technical and financial practicability as well as the social acceptance of introducing water saving measures into the present farming systems to enhance crop production and quality and reduce or even stabilize decline in groundwater on a wide scale. Evident as it may seem, this was not possible five years earlier, because of the overall context (traditional practices, social reluctance to modern technology, very low technical capacity and social structure of the production systems.) Nevertheless, the generalization of this solution - although possible - is still faced with several constraints of different natures, particularly institutional, social, legal and policy related.

Existing policies and regulations related to water development and management are often not well adapted and not adequately implemented, whereas socio-economic and institutional set-ups still need further strengthening. Tremendous efforts have been made during the past five years to elaborate new strategies and policies; but this is only the first step in the right direction of a tedious and long process, as implementation of these tools will not be easy. Crop produce is faced with serious marketing problems, both internally and for export. In addition, low quality standards and post harvest treatment make the produce lack competition. The private sector plays only a minor role, in comparison with its potential.

As it is based on Yemen, the case study presents an extreme situation; however, the issues and problems raised illustrate the global trends for the entire MENA Region. While technological improvements are essential, they should be accompanied in an integral manner with the reform of macro-policies, alleviation of rural poverty geared towards community development, strengthening of institutions particularly the private sector and enhancing marketing and export conditions.

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I. Introduction

According to current estimates, the Republic of Yemen has a population of over 17 millions and continues to grow at an annual rate of 3.7%, one of the highest in the world. Rural population represents around 70% and the illiteracy level is nearly 60%. With a per capita GDP of about US$ 270 - down from US$ 550 in 1992 - Yemen is one of the poorest countries in the world.

The total area of the country is nearly 537,000 square kilometers consisting essentially of small mountains or highlands and desert. Agriculture is the dominant sector of the economy, accounting for around 20% of the non-oil GDP and providing a source of livelihood, in the form of food and employment, to close to 60% of the population. Less than one percent of the nation's total export earnings originate from the agricultural sector. Although the total arable land is important, the potential area that can be cultivated is limited by the scarcity of rainfall and perennial water to a mean of 1.5 million hectares. Other natural resources of the country include pastures, a seacoast of over 2000 km, with important fish resources, and limited oil and gas reserves.

Production techniques are essentially of the traditional low-input-low-output type although some improvements are gradually taking place, particularly under irrigation. The typical farm size is the owner occupied smallholding with a limited practice of share cropping. The main crops grown are cereals (sorghum, wheat, millet, barley and maize), mostly under rainfed conditions. Irrigation is primarily used for fruits, vegetables and qat production.

Development of the agriculture sector is facing serious constraints resulting from policy design and sequence. Macro-economic stabilization policies of revenue enhancing and expenditure reducing measures might bring hardships to the rural poor on the one hand and squeeze financial resources available for investment in key agricultural services such as research and extension on the other. Furthermore, the supporting systems such as research and extension, marketing, credit and rural infrastructure are very poor.

II. Climate and Production Systems

Water is the determinant factor for agricultural production. The country can be divided into three natural regions, each has its own topography, climate and agricultural production systems.

II.1. Mountains and Highlands

They cover around 60% of the total area, with altitude ranging from 500 to 3600 meters. The region has lower humidity and higher rainfall than the coastal plains. Mean annual rainfall varies with altitude from 250 to 1000 mm, with the highest values in the centre of the region, around the cities of Ibb and Taiz. Traditional agricultural production in the region is based on rainfed crops, particularly sorghum, maize and cereals, in addition to fruit trees, qat and vegetables irrigated from springs and wells during dry periods of the year. The major changes witnessed in this region during the past two decades are: 1) A rapid increase of the irrigated area and hence of the number of wells; 2) a shift from certain crops, particularly coffee, to qat; 3) a shift from rainfed production to irrigation, particularly of qat, but also other crops.

II.2. Coastal Plains

These plains extend along the western and southern coasts of the country with altitude ranging from sea level to 500 meters. They are characterized by high temperature and relative humidity values and a mean annual rainfall not exceeding 100 mm. Traditional agricultural production in this region depended essentially on spate irrigation with floods from the Highlands, during the two rainy seasons.

Until recently, irrigation was limited to patches along the upstream of wadis and around shallow wells. Major crops were essentially sorghum, millet, sesame and cotton under spate irrigation; and fruit tress and vegetables in the limited areas under irrigation. This region has also undergone tremendous changes during the past two decades, with the digging and drilling of a very high number of wells and the shift towards intensive agricultural production of vegetables and forage crops as well as high water demanding crops such as tobacco, bananas, mango trees, etc. (See Box 1.)

II.3. Eastern Plain

The region represents around 15% of the total area of the country with altitude varying from less than 1000 to 2500 meters. The region is characterized by semi-arid to desert climate with very low relative humidity and a mean annual rainfall of less than 50 mm. The agricultural production system consists essentially of cereals under spate irrigation and supplementary irrigation from groundwater. Here also the number of wells has increased during the last two decades, but to a lesser extent than in the other two regions.

III. Water Resources and Irrigation

Water resources are scarce and continue to decline as a result of climate change, mining of groundwater and pollution. In 1996, the renewable amount was estimated at 2.5 billion cubic meters per year, in comparison with the annual use of 3.2 billion cubic meters. The deficit of 700 million cubic meters (expected to reach 920 million by the year 2005) is covered from the mining of groundwater. As no major rivers are found in the country, over-pumping by tube wells is estimated at 138% the natural recharge rate. This has already led to drastic groundwater level decline in several regions including the Sana’a Basin where the capital is located. Per capita renewable water resources are of the order to 150 cubic meters and continue to decline with resource decrease in absolute terms and population increase. The mining of groundwater is the result of past policies aimed at developing water resources and irrigation through highly subsidized drilling and pumping equipment, without due consideration of the necessary accompanying measures.

Agriculture is by far the largest user of water with more than 85% of the total. Irrigation is practiced mainly for fruits, vegetables and most importantly Qat which consumes between 25 and 30% of the total use in irrigation. As a result of an increase in the number of wells during the past two decades, the total irrigated area expanded rapidly, at the expense of rainfed and spate irrigation areas. It is currently estimated at about 250,000 hectares, in comparison with Wadi (river) spate irrigation which declined sharply to only about 150,000 ha. Despite water shortage, irrigation technology and management are still of the traditional type with very low on-farm efficiency (35-40%.)

IV. The Critical Issues

Water shortage in Yemen is without any doubt the most crucial issue the country is facing and will likely continue to face in the future unless appropriate measures are taken. In addition to being one of the poorest countries in terms of per capita water resources, several other problems exacerbate the situation and make it the major constraint threatening social stability and standing against economic growth, particularly in rural areas:

1. Lack of sustainability of the resources as the current use from most aquifers is much higher than natural recharge. This trend will ultimately lead to the depletion of groundwater with all of the consequences, particularly on food production, drinking water supply and the environment;

2. Demand on water resources continues to grow with the population increase and the higher needs to meet food requirements, particularly in rural areas where agriculture is the main source of food and employment;

3. Pollution of water is reaching alarming levels and reducing further the already limited water resources, in particular in coastal aquifers as a result of seawater intrusion, but also in other areas because of domestic and industrial residues;

4. Of the total water use in the country, agriculture accounts for nearly 85%. However, only a limited portion of this share is used effectively for crop production, the rest is lost to evaporation and deep percolation as a result of conventional water management methods still prevailing in the country. Traditional surface irrigation and low performance of on-farm water management result in very low irrigation efficiency and the loss of a high share of the total water use in agriculture.

The immediate consequence of this continuous decline in water resource is household food shortage especially for poor families in the vulnerable rural areas. As most renewable water resources have already been harnessed for use**, the only viable option left is the improvement of the management of the available resources, through the introduction of adequate technologies and management tools.**

IV. The Chellenge

Conscious of these issues, the Government launched in 1995 a wide-scale program to construct small and medium-size rain and flood dams with community participation, in areas that rely on rainfed agriculture or where groundwater was being depleted. Efforts were also made, under various donors and nationally-supported programs, to improve the general efficiency of irrigation from groundwater resources. Given the low overall efficiency of traditional surface irrigation systems, it was felt that there was considerable scope, through improving irrigation efficiency, for increasing the water use efficiency while saving on water use. At the same time, several steps were taken in order to fill the gaps in regulations, policies, and institutional set-up and strengthening.

Earlier attempts to introduce modern irrigation technologies and management tools undertaken in the eighties had failed because of the manner projects were designed and implemented. A rapid evaluation shows that the main reasons for failure were as follows:

- Farmers did not participate in any way; the entire cost, including installation, was supported by the Government. Farmers did not even give the assurance to keep and maintain the installed schemes.
- Farmers who knew very little if any on the newly introduced technology did not receive sufficient training on their operation and maintenance.
- No provisions were taken to ensure the availability of spare parts and to build technical capacity for maintenance and repair.
- No follow-up/back-up from advisory services once projects ended.
- Inadequate technical studies lead to serious operation problems.
- Insufficient feasibility studies which, if undertaken, would have predicted most of these problems.

Building on the lessons learnt from the past, efforts in the nineties were oriented towards more involvement of farmers to share the costs on one hand, and the development of strategies and policies aimed at sustainable resources management on the other. This was accomplished through the development and implementation of several projects aimed at introducing modern irrigation technology and on-farm water management tools, in a participatory manner. The technology consists of PVC and Galvanized iron pipes for water transport and distribution to reduce water losses, and drip, sprinkler and bubbler systems in pilot farms, for demonstration purposes. The most important of which is the IDA/WB financed Land and Water Conservation Project which aimed initially at equipping 8500 hectares with PVC and GI pipes and 100 hectares with drip, sprinkler and pilots schemes, for demonstration purposes. During its implementation and/or as part of it, several changes took place in terms of institutions and policies. These concern in particular the creation of the National Water Resources Authority as the sole national institution in charge of water resources development and management, and the elaboration of a national water resources strategy, a water law, the irrigation policy and irrigation law, to cite only a few.

V. A Sample Project: Land and Water Conservation Project

V.1. Introduction

The Land and Water Conservation Project is an investment project which considers both the aspects of demand and offer of water. In the course of its implementation, Yemen went through an important process regarding the elaboration of sound policies on water resources and the building of institutions capable of managing this strategic resource. The establishment of the National Water Resources Authority and the formulation of the national water strategy as well as of the irrigation policy constitute the output of these efforts. Given the share of water use by agriculture, the irrigation policy is without any doubt the most important component of the national water strategy. The Irrigation component of the LWCP falls along the lines of these policies, be it for water conservation in general or the improvement of water-use efficiency in irrigation in particular. Thus, although the project preceded the policy, it is a direct implementation of it.

Probably the most important indicator of the LWCP is the water saving at the farm level and its impact both on the overall water use by participating farms and on the draft from groundwater. The evaluation of the project is therefore based on these savings and their impacts (direct impact on groundwater and indirect impacts such as the improvement of farmers' social and economic conditions, technical capacity, etc.) The other indicators used for assessing the benefits of the project are all linked to the water savings; these are:

- Value of the volume of water saved,
- Decrease in irrigation time and labor,
- Savings in fuel,
- Impact of decreasing pumping time on the amortization of the pumping station,
- Increase in the cropping intensity,
- Change in cropping patterns such as the introduction of crops with higher value added,
- Increase in the irrigated area,
- Etc.

V. 2. Methodology adopted for assessing water savings

Intensive training was provided through Technical Assistance from the Food and Agriculture Organization of the United Nations (FAO) to the staff in charge of the assessment. Questionnaires suitable for every type of farm were provided and the staff was familiarized with their use.

In addition, the trained staff from the Project Implementing Units (PIU) collected the field data under the close supervision of International Experts. The latter also collected data directly from farms visited for various purposes such as assisting for the design of irrigation schemes, monitoring project implementation, providing guidance on operation and management of irrigation networks, etc. A synthesis of the results of the treated data is given below.

V.3. Results and Discussion

According to the project document, the irrigation efficiency prior to the introduction of PVC and GI pipes was 35%. The targeted figure after the introduction of this equipment was 50%. To attain this output, the project sought the introduction of new technology, particularly PVC and GI pipes, to improve the efficiency of water transportation and distribution. At the farm level, the project was designed for supplying 130 m of PVC and 90 m of GI per hectare. However, most farmers have used less than these quantities (see below); therefore the area covered by this type of equipment reached over 10,000 hectares instead of the initially planned 8,500. For the same reason, the value of efficiency reached in participating farms is expected to be not as high as 50%.

The measurements of water savings at the farm level showed that they vary from 10 to over 50% depending on factors such as the accuracy of the design and installation of the system, the capacity of the farmer to operate and maintain his system adequately, the soil type, the crop, etc. At the regional level, the mean economy in water use represents no less than 20% and can reach up to nearly 35%, particularly north-west of the country where most of the farms were equipped with bubbler irrigation systems (see Box 1.) Table 1 synthesizes the water saving results by region.

Given the large amounts of water applied traditionally by farmers, these savings represent also large volumes at the farm level. Conventionally, farmers apply up to three times the required gross volumes of water, i.e. up to twenty thousand cubic meters per hectare and per year, when water is available at low cost. The introduction of PVC and GI pipes is helping reduce the losses tremendously as shown in the tables below. The benefits of these savings of farmers, be it directly or indirectly, are fully acknowledged not only by all participating farmers with no exception, but also by those who could not participate for several reasons. In this regard, it can be concluded that there is consensus among all farmers regarding the important benefits of the project on participating farmers and its positive impact on groundwater, especially if the majority of farmers adopt the technology in the future. Evident as it may appear, this was not the situation a few years ago given the social context dominated by traditional customs and practices.

Similar encouraging results have been obtained with Bubbler irrigation, with the difference that a lot of capacity building is still needed to allow engineers to design and install these systems appropriately. Moreover, training of farmers on their operation and maintenance, through sound advisory services, is completely lacking. As a result, although extremely promising and already profiting especially in the regions of Abs (see Box 1) and Tihama, the potential of this technology still needs a lot of efforts in terms of investment, particularly in capacity and institutional building, including extension on on-farm water use.

As for Sprinkler irrigation and to a much larger extent Drip irrigation, the results are way below expectations. Here also, the need for additional capacity building to master this delicate technology is still very high. So far, three farms equipped with drip systems have already abandoned and taken them off their land. However, this result is quite normal given the delicacy of this type of technology and the inadequate environment especially the low technical capacity and the lack of advisory services on water in general and irrigation in particular.

Box 1

The Abs Region, Northwest of Yemen:
An example of uncontrolled self expansion of modern irrigation technology

In the Abs region, there is already an estimated number of 225000 mango trees which have been planted during the past ten years. Of this total, more than 30000 trees are already productive. Considering a planting pattern of 80 trees per hectare, this corresponds to an area of over 2800 hectares almost all of which equipped with modern irrigation systems, particularly Bubbler. The self-expansion of modern techniques proves their better efficiency and capacity for saving water, fuel, operation time and labor. The LWCP has provided PVC for over 500 hectares and bubbler and drip systems for about 12 hectares; all the rest is from the market.

Visits to farms show that there are still serious problems with design as well as with installation, operation and maintenance of the networks. The engineers who conducted the preliminary studies and undertook the design and installation of the systems acknowledge their limitations and additional training needs.

From the operational standpoint, farmers are still applying too much water, in comparison with the crop requirements. Similarly, the system operation is not as recommended for optimum savings and efficiency. These and several other deficiencies result from the lack of appropriate advisory services on on-farm water management. It also shows that the actual savings are far below the potential of the installed systems.

Despite all this, farmers are very satisfied with their modern networks for water transportation, distribution and application. All farmers agree on the importance of the new technology for saving not only large amounts of water, but also operation time, fuel and labor costs. Saving figures, as estimated by farmers and farm managers, range from a minimum of 20% to a maximum of over 50%. Our assessment finds an average of over 35%. In terms of volume, this corresponds to saving an average of 4500 m^3 per hectare and per year, or 13.5 million cubic meters per year for the 3000 hectares of the region. This volume is equivalent to about 170 times that of a medium size dam with a capacity of 80,000 m^3.

Unfortunately, the Abs region may not last long without serious problems, unless urgent and adequate measures are taken. Despite the proximity of the sea and the rapid increase of the number of wells, there is no groundwater monitoring in this extremely sensitive region. The number of wells is estimated at about 400 with salinity of groundwater increasing from about 1 mmhos/cm near the recharge zone (along the wadi) to over 1.4 mmhos/cm at the extreme north. The number of wells is continuously increasing and so is the expansion of the irrigated area without knowing if there is enough water. So far, no drawdown has been noticed despite the large number of operating wells, whereas salinity level has risen by an average of 0.2 mmhos/cm, which could be the sign of seawater intrusion.

V.4. The Economics of Water Savings

The investment by farmers for purchasing and installing modern irrigation equipment is recovered essentially through the water savings and the improvement in yield and quality of produce; in addition to any added value resulting from changes in cropping patterns or increase in the irrigated area. The intensive field visits revealed that all of these elements have contributed to the betterment of the economic and financial situation of participating farms. As far as water savings are concerned, the results from all regions are summarized in table 2. The indicated values correspond to the means of variables and parameters in the project area, for each region. As farmers do not pay for the usage of water, the indicated cost is based only on the fixed costs for digging and equipping wells and on the operational costs. Then, the investment by farmers for purchasing irrigation equipment from the Project (50% of the real price plus study and installation) was assessed under different interest rates. These two components (cost of water and investment in irrigation equipment) served for determining the recovery period of the investment, based on water savings. A synthesis of the results is given in table 3.

Results show that the cost of water varies from 4 to over 30 Yemeni Rials per cubic meter depending on the region and the interest rate; the mean for all seven regions at zero interest rate is around eight Rials per cubic meter. This cost remains relatively low considering the deep water tables in certain regions and the high interest rate practiced by the lending bank. It explains in part why farmers still apply large volumes of water in comparison with the crop requirements. The low cost of fuel also explains why water is still affordable especially by farmers who practice high value cash crops such as Qat. It should be mentioned here that Qat was exlcuded from this project.

If water saving is considered as the only benefit made from the investment, the latter is recovered in 1 to less than 4 years, with the largest figure corresponding to the region where water table is the deepest and the interest rate of the loan is 23%. This clearly shows that investment in water conveyance and distribution equipment is extremely beneficial for farmers. As for the more sophisticated irrigation systems, their costs are recovered within a period of 7 to 8 years (Box 2.)

From the standpoint of water savings per se, they vary between 1,900 and 3,400 m^3 per hectare and per year and represent no less than 20% and up to 30% of what farmers were applying before the introduction on pipes. The mean over all regions is nearly 2800 m^3/ha. With bubbler irrigation in the Abs Region, the water savings reach a mean of 4,500 cubic meters per hectare or 35%. When extrapolated to all participating farms, these savings amount to large volumes of precious water being conserved. At the term of the project, the savings resulting from all participating farms represent around thirty-eight million cubic meters[3] per year (more than 10670 ha). For comparison, this volume corresponds to that of 475 dams each having the same capacity as the average small dam in Yemen (80,000 m^3), assuming that the dam gets filled every year which may not be the case. The total cost of an average dam is about 30 million Yemeni Rials. At the current cost of water, the annual water savings from participating farms in LWCP are equivalent to 296 million Rials or over 1.8 million dollars. This comparison gives an idea about the alternatives that should be given priority for investing in water resources development and management. Without the Abs region, these figures would be 254 million Yemeni Rials or US$1.5 million.

In addition to water savings per se, participating farms have also benefited through a reduction in labor and a similar reduction in the time of operation and hence an increase in the life span of the head station. The mean benefit from these corresponds to at least 10,000 Rials per hectare and per year which reduces even further the recovery period of the equipment. Similar benefits have also been obtained from the improvements in yield and quality.

[3] The figure includes the savings in the Abs Region. Without this region, the total volume of water savings would be 24.5 million cubic meters per year, corresponding to a total cost of 254 million Yemeni Rials or US$ 1.5 million per year.

Epilogue

The results presented above seem to be very encouraging. They show that under all the cropping systems irrigated from groundwater and within the traditional social system of Yemen, it is technically possible to achieve large water savings. If improved, which can easily be achieved, and generalized to a majority of the area currently under irrigation, the savings would be not only much larger than the current water deficit, but would also allow an important expansion of the irrigated area. And this would solve the current crisis facing the country.

Obvious from the logical standpoint, this solution is far away from being realistic when put in the very complex context of not only Yemen but most countries of the Near East Region with similar problems. The issue of water crisis is more than just technical, although it is very important to master the technology. Sustainable water management is a comprehensive, integrated process consisting of several pieces that are inter-linked in a very delicate manner and linking water with national development.

In the particular case of Yemen, several pieces of the process are either still lacking or in infancy. Tremendous efforts have been made in the course of the last five years in terms of elaborating the soft part. Near perfect policies, strategies and regulations have been developed; a giant step in the right direction. However rather than being an objective by themselves, they are only the first steps in a long way. Action-oriented measures are needed to implement these policies.

Under the present situation, the benefits made from irrigation are very low because of low yields and quality, low post harvest treatment, unregulated marketing and the lack of competitiveness for exportation. This in turn results in a low output per unit of water used for irrigation and decreases the value of water as an economic good. This situation could be reversed by orienting production towards the needs of the international market, such as the production of organic food for which the conditions are adequate in Yemen.

Involvement of communities in a partnership manner and their full participation at all levels are necessary to ensure the adaptability of regulations and their enforcement by these communities themselves. In this regard, clear contracts have to be made and responsibilities identified and agreed upon. Partnership is a means to avoid generalized subsidies and paternalism by the State, thus targeting assistance towards the needy groups and community development.

Last but not least, institutions need to be established or strengthened as required and given full power, means and clear mandates. In return they should be made accountable and incentives should be linked to productivity. Where appropriate, the private sector should be encouraged to take over public institutions on the basis of merit and sound competition.

Table 1: Synthesis of Water Savings Data by Region

Project Region	Lahej	Abyan	Tihama	North(*)	Abs Region	Dhamar	Taiz	Shabwa	PROJECT TOTAL (T) OR MEAN (M)
Area covered by PVC and GI pipes at the term of the Project (ha)	840	830	2990	2900		1035	1050	1025	T: 10,670
Area covered by modern irrigation systems as of June 30 2000 (actual/planned, in ha)	5/5	4/6	12/12	8/12		7/11	7/12	6/8	T: 49/66
Mean water use at farm level without project (m^3/ha)	10,400	10,600	11,300	11,000	13,000	10,700	10,800	7,600	M: 10,700
Mean water use at farm level with project (m^3/ha)	8,300	8,000	7,900	8,300	8,500	8,600	8,100	5,700	M: 8,000
Water savings at the farm: - (%) - (m^3/ha)	20 2,100	25 2,600	30 3,400	25 2,700	35 4,500	20 2,100	25 2,700	25 1,900	M: 25.6% M: 2750
Water savings in the region as a result of the project (m^3/year)(**)	1,764,000	2,158,000	10,170,000	7,830,000	13,500,000	2,174,000	2,800,000	1,900,000	T: 38,000,000
Current cost of water (YR/m^3)	6.37	4.62	5.59	13.74	3.1	9.05	10.86	8.65	M: 8.0
Cost of water saved in the region(**): YR/year US$/year	11,237,000 **68,000**	9,970,000 **60,000**	57,000,000 **344,000**	108,000,000 **652,000**	42,000,000 **260,000**	19,700,000 **119,000**	31,000,000 **187,000**	16,800,000 **102,000**	T: 296,000,000 **T: 1,790,000**

(*) Excluding the Abs Region

(**) In the Abs region, figures of water savings and their costs are given in Box 2. The region was equipped with modern irrigation technology, both from the project and the market. Installation however was by the LWCP technical manpower for the largest part.

Table 2 : Synthesis of the Data used for determining the Cost Recovery Period of Irrigation Equipment

	Lahej	Abyan	Tihama	Northern(*)	Dhamar	Taiz	Shabwa
Depth of water table (m)	40	30	40	100	100	80	40
Depth of wells (m)	100	60	80	150	150	130	70
Discharge from wells (l/s)	10	11	10	5.5	8	6	8.5
Irrigated area per well (ha)	8	9	8	4.5	7	5	6
Daily pumping time (h)	6.3	6.3	6.8	6.8	7.1	6.8	4.1
Engine horsepower (HP)	28	22	25	28	28	28	22
Fuel consumption (liters/h)	4	3.5	3.5	4.5	4.5	4.0	3.5
Drilling and casing cost (10^6 YR)	1.3	0.8	1.0	3.0	2.7	2.0	1.0
Fuel tank & well shelter (10^6 YR)	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cost of Engine and Pump (10^6 YR)	2.5	2.0	2.5	2.6	2.7	2.5	2.0
Oil, lubricants, etc. (10^3 YR/year)	15	13	17	13	23	12	15
Maintenance costs (10^3 YR/year)	20	18	20	20	25	20	18
Total area equipped with pipes from the Project (ha) :	840	830	2990	2900	1035	1050	1025
LWCP PVC cost (10^3 YR/ha) :	40	30	45	40	40	40	40
Mean pipe length used (m/ha)				136			
PVC :	100	93	90	100	127	132	131
GI :	94	-	-		92	93	-

Life span of well (Years):	15
Life span fuel tank & shelter (Yr):	15
Life span, Engine and Pump (Yr):	8
Irrigation labor cost (YR/day) :	400

(*) Excluding the Abs Region

Table 3 : Cost Recovery Period and other Economic Data for each Region

	Lahej.	Abyan	Tihama	Northern(*)	Dhamar	Taiz	Shabwa
Average irrigated area per farm (ha.)	8	9	8	4.5	7	5	6
Fixed annual costs at ZIR(**) (10^3 YR)	407	310	387	532	525	453	323
Operational Costs at ZIR (10^3 YR/Yr.)	122	110	116	144	154	130	73
Total costs at ZIR (10^3 YR/Yr.)	529	420	503	676	679	583	396
Water use (10^3 m^3/ha./Yr.)	10.4	10.6	11.3	11	10.7	10.8	7.6
Cost of water at ZIR (YR/m^3)	6.37	4.62	5.59	13.74	9.05	10.86	8.65
Investment in PVC at ZIR (10^3 YR/ha.)	40	30	45	40	40	40	40
Water savings (10^3 m^3/ha./Yr.)	2.1	2.6	3.4	2.7	2.1	2.7	1.9
Cost of Saved Water at ZIR (10^3 YR/ha/Yr.)	13.4	12.0	19.0	37.0	19.0	29.3	16.5
Recovery period of investment in PVC through water savings (Yr.)							
Zero Interest Rate	3.0	2.5	2.4	1.1	2.1	1.4	2.4
10%-5Yr loan	3.3	2.8	2.6	1.2	2.3	1.5	2.6
16%-5Yr loan	3.4	2.9	2.7	1.2	2.4	1.6	2.7
23%-5Yr loan	3.5	3.3	2.8	1.3	2.5	1.7	2.8
Area to be covered by PVC At term of LWCP (ha.)	840	830	2990	2900	1035	1050	1025
Volume of water pumped before LWCP (10^6 m^3/Yr.)	6.2	6.0	28.25	33.0	6.4	9.7	7.8
Volume of water saved at term of LWCP (10^6 m^3/Yr.)	1.8	2.2	10.2	7.8	2.2	2.8	1.9
Cost of water saved at current price with ZIR (10^3 US$/Yr)	68	60	344	652	119	187	102

(*) : Excluding the Abs region (**) : ZIR : Zero Interest Rate YR: Yemeni Rial

Box 2: Typical Investment in Irrigation in the Abs Region

Farm of 30 hectares with two wells

1. Investment (Yemeni Rials)

Well (80 m deep): 1, 200, 000 x 2 wells
Pump and Engine: 2, 400, 000 x 2 wells
Irrigation System
(PVC / Bubbler): 100,000 Rials/ha or 3,000,000 Rials for 30-ha farm

Total cost per hectare: 220, 000 Rials or $US 1,300 to 1,400

The irrigation system (often bubbler) allows for an average saving of 20 to 50% depending on its design, installation and management. In terms of volume, the savings amount to an average of 4500 m^3 per hectare and per year.

2. Local Cost of Water (Yemeni Rials, at zero interest rate)

Fixed Total Costs:	3,700,000
Fixed Annual Costs:	387,000
Annual Operation Costs:	209,000
Total Annual Costs:	**596,000**
Cost of Water (YR/m^3):	**3.1**

3. Recovery Period of Investment in Irrigation based on Water Savings

Investment Cost in Irrigation Systems (YR/ha.) : 100,000

Water Savings Induced by Irrigation System (per year):

	Per hectare	For 15-ha per well
Water Use prior to installation of irrigation system (m^3)	13,000	195,000
Water Use after installation of irrigation system (35%)	8,500	127,000
Volume of water saved (m^3):	4,500	68,000

Cost of water Saved at no interest rate (YR/ha/year): 14,000

Recovery period of Irrigation System based on Water Savings: 7 years

4. Water Savings in the Abs Region

Area covered presently by pipes and localized (ha): approx. 3,000
Volume of water pumped before installation (m^3/year): 39,000,000
Volume of water saved by modern systems (m^3/year): 13,500,000
Value of water saved at term of project, based on the current local cost with no interest rate (YR/year): 42,000,000 or approx. US$ 260,000.