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Water Management and Conservation Measures Under Semi-Arid and Arid Conditions

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ABSTRACT

In the near East Region, natural aridity is a majour constraint to production and the provision of irrigation water is one of the most important factors for increasing agricultural production. However, this constraint could be mitigated by balancing actions with respect to the hydrological cycle so that the available water resources would serve the needs of the country. Water is the most manageable of the natural resources, in that it can be transported, stored, diverted and recycled. This presentation discusses some fundamentals, principles, and techniques which could be incorporated into an integrated land and water management system aimed at controlling the hydrological cycle and ensuring sustainable development. Basically, there are two approaches, one is increasing the supply of usable water and the second is reducing the demand for water.

The greatest opportunity for increasing water supply is to improve existing water systems, and through improved water management at the farm level. Rainfall harvesting, runoff agriculture, recharge of groundwater, resuse of wastewater, the use of brackish and sea water, desalination of brackish and sea water, artificial rain, and fog harvesting all contribute considerably to the water supply.

On the other hand, measures to reduce the demand for water are as important as those to find additional sources of water. Such measures include: reducing evaporation from water surface in reservoirs; reducing seepage losses by lining open canals and in conveying water in pipes; reducing water application losses through improved irrigation methods such as level basins, surge flow for automated surface irrigiation, sprinkler, drip irrigation, low-head bubbler system and other methods; reducing percolation losses in sandy soils by the use of underground moisture barriers; reducing transpiration from plant leaves without affecting the yield; minimizing the consumptive use of water by crops grown in controlled environments; and finally the use of hydrophilic soil amendments to minimize soil moisture losses by either evaporation or deep seepage.

sustainable pop. growth?

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INTRODUCTION

Because of the aridity prevailing in the Arab countries, it is the poorest region in the world in terms of water resources, globally and per inhabitant, even when considering the contribution of the rivers flowing from the bordering and more humid regions of tropical Africa (the Nile) or Turkey (The Tigress & Euphrates). However, the water resources distribution within this vast area, extending over two continents, is far from being uniform. Rainfall is low to very low in most of the Region. (Table 1.)

Table 1. Extent of Aridity in the Arab Countries as Reflected in Rainfall Data

Region or Country	Total area 1000 sq.km.	Amount of Rainfall				A+B % of Total
		A Less than 100 mm		B 100-400 mm		
		Area (1000 sq.km.)	%	Area (1000 sq.km.)	%	
North Africa 1/	5 751	4 864	85	653	11	96
Near East 2/	3 705	3 033	79	589	16	95
Sudan	2 625	764	29	500	19	48
Somalia	637	170	27	300	47	74
Total	12718	8831	69	2042	16	85

1/ Algeria , Egypt , Libya , Morocco and Tunisia.
2/ Bahrain , Iraq , Jordan , Kuwait , Oman People's Democratic Republic of Yemen , Qatar , Saudi Arabia , Syria , United Arab Emirates , Yemen Arab Republic
* *Source: Reference No. 3 , Table 1. , Page 2.*

From table No. 1 it could be noted that, excluding Sudan and Somalia, about 83% of the area of the Arab countries receive less than 100 mm of annual rainfall and about 13% receives 100 to 400 mm of rainfall annually, and only about 4% of the total area receives more than 400 mm of annual rainfall.

Hence aridity is a major constraints to production and there is very little can be done to change it. However, man could control his actions with respects to the hydrological cycle so that a given amount of water would serve his needs without undesirable side effects, such as desertification. Since it can be transported, stored, diverted and recycled, water is the most manageable of the natural resources.

The potential of irrigation water in raising both food production and the living standards of the rural poor has long been recognized. Irrigated agriculture in the Arab countries amount to about 30% of the cultivated areas but its production amounts to about 75% of the total value of agricultural production[2]. In large parts of the Region no crops can be grown without irrigation water. Therefore many countries gave top priority for the development of irrigation.

Consequently the easily accessible water resources, surface and groundwater of good quality have now been almost entirely committed.

At present great efforts are being made in the Region, to make additional water available. In all large river basins, majour surface storage reservoirs have been built or under construction (Euphrates, Tigris, and Nile). In other parts of the Region (Jordan, North Africa, Saudi Arabia, Syria & Yemen) a number of smaller dams are in different stages of planning or execution. Saudi Arabia and Yemen Arab Republic are planning to convert the traditional spate irrigation to perennial irrigation by better control of flood water of these seasonal wadis, and the use of the groundwater reservoirs in the alluvial plains of these wadis. The large groundwater basins known so far (Algeria, Arab Gulf States, Jordan, Egypt, Libya, Saudi Arabia, Sudan, Syria and Tunisia) are being developed.

This process of ripid agricultural development under irrigation was accompanied by the process of desertification, manifested in waterlogging and salinity of irrigated lands and, in the increasing salinity of groundwater and falling water tables due to overpumping.

On the other hand, the scarcity of water supplies, which are badly needed to meet the needs of population growth and rising standard of living has given cause of concern in formulating of national development plans in these countries. It is gratifying to report that decission makers are being increasingly involved in devising ways to optimize the use of the available water supplies as well as augmenting the available water resources by conventional and non-conventional sources. The latter includes two programmes, one is desalinisation of brackish and sea water and the other is the treatment of sewage effluent and its reuse mainly for irrigation purposes.

From the above discussion it becomes evident that there is an urgent need to introduce appropriate technologies that will result in increasing water supply and minimizing water use. Such techniques could be listed under two main headings, namely: Water Development Techniques and Water Conservation Measures[10]. The main techniques for Water Development include the following:

- Water harvesting.
- Recycling of Water.
- Desalting of Brackish and Salty Water.
- Use of Brackish Water.
- Weather Modification.

On the other hand the Water Conservation includes the followings main measures:

- Improved irrigation Systems and Water management at the field level.
- Reducing evaporation from water surfaces, and soil surfaces.
- Maximizing production from one unit of water.

This paper discusses some of the above techniques and measures which are relevant to the Arab Countries.

INCREASING THE EFFICIENCY OF IRRIGATION WATER:

The greatest opportunity for increasing water supply is to improve the efficiency of existing irrigation projects. It is estimated (1994) that about 90% of the used water resources in the Arab Countries was utilized for irrigated agriculture, 6% for domestic uses and 4% for industrial purposes. Hence out of the total water used of about 182 Milliard Cubic Meter about 165 Milliard Cubic Meter was used for irrigation[(2)]. The overall efficiency of irrigation water use is estimated at about 50%. This is because out of the total irrigated area of 14.4 million ha, about 85% (12.3 million ha) is using conventional surface irrigation and only 15% (2.1 million ha) is using improved irriagation systems i.e., sprinkler and localised irrigation. The latter amounted only to about 1.6% (about 228 000 ha)[(7)]. Hence, rehabilitation of existing supply system is needed, where the distribution system needs to be upgraded and control structures introduced, a suitable drainage system installed, the farmers' fields graded or leveled, and water should be given to the crop at the right time and in the right amounts. This should be accompanied by intensive training programs for farmers and field irrigation personnel as well as for advisory staff and scheme operators.

The introduction of improved irrigation systems such as, improved surface irrigation, using dead level basins and graded borders using laser for land levelling and the increase use of localized irrigation systems should be implemented. This should result in increasing the overall irrigation efficiency from the present 50% to at least 75%, which will mean an annual savings of about 41 Milliard M^3 which becomes available for use for different purposes. This leads to the conclusion that this issue should be given a top priority in the programs aiming at achieving water and food security in the Arab World.

It is encouraging to report that some Arab countries had introduced improved irrigation systems as it may be noted from table 2.

Table 2. Irrigation Systems Used In Some Arab Countries as Percentage of Total.

Country	Surface	Sprinkler	Drip
Jordan	32	8	60
Egypt	80	8	2
Morocco	85	13	2
Oman	94	3	3
Saudi Arabia	34	64	2
Sudan	100	-	-
Syria	97	2	1
Tunis	81	17	2

* *Source: Reference No. 2 , Table 6 , Page 25.*

TREATMENT AND REUSE OF WASTEWATER:

Next in importance will be the treatment of sewage effluent and other sources of wastewater and their reuse, mainly, for irrigation. This source of water will be increasing parallel with the increase of population together with the rise of standard of living. It is estimated that at least 50% of the municipal water supply could be retrieved and utilized for irrigation. This will not only contribute to solving the problem of water shortage, but it will also result in reducing the cost of the effluent treatment if it is compared with that required for the protection of the environment and avoiding health hazard. In addition this source is rich in plant nutrients, namely; nitrogen, phosphorous, potash and organic matter.

At present about 1100 MCM of treated wastewater is being used annually mainly for irrigation in the Arab Countries (Table 3). Many Arab Countries have adopted a policy to treat and reuse all available effluent. In the future several Arab Countries, particularly the Arab Gulf States will depend mainly on this source of water for irrigation purposes(11).

In this regard it may be of interest to quote from the Jordan water policy which states as follows: "Wastewater shall not be managed as "Waste". It shall be collected and treated to standards that allow its reuse in unrestricted irrigation and other non-domestic purposes, including groundwater recharge. Appropriate wastewater treatment technologies shall be adopted with due considereations to economy in energy consumption and quality assurance of the effluent for safe use in different purposes. Consideration shall be given to blending of the treated effluent with fresher water for appropriate reuse".(9)

Table 4. Water Harvesting Catchment Construction: Water Costs* (In Dollars) Per Thousands Of Liters Of Runoff For Varying Annual Precipitation Rates

	Catchment Treatment	Range (mm) Average (mm)	100-200 (150)	200-300 (250)	300-450 (375)	400-600 (500)	400-850 (625)	400-900 (750)	600-1200 (900)	800-1200 (1000)
I	**Earth Structures**									
	Land Cleaning		0.28	0.17	0.11	0.08	0.07	0.06	0.05	0.04
	Road Catchments		0.51	0.31	0.20	0.15	0.12	0.10	0.09	0.08
II	**Chemical**									
	Sodium Chloride		0.36	0.21	0.14	0.11	0.08	0.07	0.06	0.05
	Sodium Carbonate		0.59	0.35	0.24	0.18	0.14	0.12	0.10	0.09
	Wax (Paraffin)		2.02	1.21	0.81	0.61	0.48	0.40	0.35	0.30
III	**Asphalt**									
	Fiberglass Asphalt Chipcoated (FAC)		0.60	0.35	0.24	0.18	0.14	0.12	0.10	0.09
	Asphalt-Plastic-Asphaslt-Chipcoated (APAC)		0.80	0.48	0.32	0.24	0.19	0.16	0.14	0.12
	Asphalt - Rubber		1.06	0.64	0.42	0.32	0.25	0.21	0.18	0.16
	Aphalt - Concrete		3.01	1.81	1.21	0.90	0.72	0.60	0.52	0.45
IV	**Synthetic Membranes**									
	Graveled Polyethlene Plastic		0.88	0.53	0.35	0.26	0.21	0.17	0.15	0.13
	Reinforced Mortar-Covered Polyethlene Plastic		1.65	0.99	0.66	0.50	0.40	0.33	0.28	0.24
	Sheet Metal		2.48	1.48	0.99	0.74	0.59	0.49	0.32	0.37
	Chlorinated Polyethlene (PCE)		5.04	3.03	2.02	1.88	1.21	1.01	0.86	0.76
	Artificial Rubber		6.26	3.75	2.50	1.88	1.50	1.25	1.07	0.95

* Water costs are based on capital cost, average catchment efficiency, annual maintenance and average 20 year annual amortization at 8% interest rate.
Water costs do not consider storage losses.

Source: Reference No. 5.

Table 3. Conventional and Non-Conventional Water Resources Used in the Arab Countries (1994)
Figures in million m^3

Country	Surface Water	Ground Water	Treated Water	Desalinised Water	Total	Population Million	m^3/Capita
Jordan	287	512	50	3	852	4.1	208
United Arab E.	20	900	110	385	1415	2.2	650
Bahrain	-	150	10	75	235	0.6	422
Tunis	400	1536	100	8.3	2044.3	8.8	233
Algiers	2600	2000	-	64	4664	27.2	172
Djibouti	-	20	-	0.1	20.1	0.5	41
Saudi Arabia	450	3000	217	795	4462	17.0	262
Sudan	21800	770	-	0.4	22570.4	25.6	882
Syria	7810	3510	50	2	11372	13.8	821
Somalia	4000	35	-	0.1	4035.1	9.8	413
Iraq	47600	1500	-	7.4	49107.4	20.0	2455
Oman	55	410	26	34	525	2.5	211
Palestine	-	260	30	-	290	2.3	126
Qatar	-	110	50	98.6	258.6	0.6	436
Kuwait	-	320	80	240	640	1.5	436
Lebanon	400	600	2	-	1002	3.0	339
Libya	60	3430	110	210	3810	4.8	785
Egypt	55500	3100	200	25	58825	57.6	1022
Morocco	7500	3500	59	1	11060	26.1	424
Mouritania	670	70	-	2	742	2.2	335
Yemen	2600	1200	9	10	3819	15.8	242
Total	151752	26933	1102.5	1960.9	181748.4	245.8	739
% of Total	83.5	14.8	0.6	1.1	100		

Source: Reference No. 2, Appendix 4, Page 55, & Reference No. 6, Table No. 2, Page 3.

WATER HARVESTING

In the Arab Countries the potential of water harvesting is tremendous. Though rain falls infrequently in arid lands but it comprises considerable amount of water. Rainwater harvesting is possible in areas with as little as 50-80 mm average rainfall. In arid and semi arid areas the average rainfall vastly exceed the stream flow. Some of this lost water is transpired by useful vegetation but most of it soaks into dry soils and then evaporates directly from the soil or is used by low-value vegetation. Harvesting rainwater can provides water for regions where other sources are too distant or too costly or where wells are not practical because of unfavorable geology or excessive drilling costs. Rainwater harvesting is practically suited to supplying water for small villages, schools, households, livestock and wildlife. Water harvesting by water spreaders, pits, contour furrows and borders and contour strip ploughing are most promising runoff agricultural techniques. Some of these techniques are widely used in connection with fruit trees, but hardly used in range lands which occupies about 30% of the geographic areas and is about 7 times the present cultivated areas. Hence water harvesting in the range lands has a great potential in increasing the forage production of these areas on which most of the feed of the livestock of the region depends. It will also provide drinking water for domestic animals which in most cases, is the limiting factor, for the utilization of the ranges[8].

Furthermore there are many seasonal wadis networks through which water flow takes place from few hours to several days and the information available on these wadis are very limited. Indications point out that the potential of these wadis is considerable, but it is lost in the depressions, sabakhs and seas. The development of the water of these wadis, using the appropriate water harvesting methods, will provide good source of water for municipal and agricultural uses and in some cases for the recharge of ground water, thus contributing to the increase of water supply[4].

Methods and Material Used for Surface Water Harvesting:

Rainfall runoff can be increased by using many methods, such as: (i) Land alteration by making ditches or rockwalls along hillside contours, clearing away rocks and vegetations and compacting the soil surface. (ii) Chemical treatment which involves the use of chemicals, such as sodium salts. Runoff from bare soil can be increased by dispersing its aggregate particles with sodium salts to reduce permeability. The use of sodium salts to increase runoff is very promising because of its low initial cost. (iii) Ground cover which include using material such as plastic sheets, or reinforced artificial rubber sheeting or Nylon reinforced sheeting or by placing a layer of fiberglass matting on the soil and coating it with asphalt compounds, or using asphalt pavements by spraying asphalt compound on the soil surface.[5]

Evaluation studies were carried out by the University of Arizona in Tucson on the cost of harvested water using different catchment treatments under varying annual precipitation rates. The results of these studies are summarised in Table 4.

From Table 4. it could be noted that the cost of water harvested by surface runoff depends on the kind of treatment used and the average rainfall. The average cost of harvested cubic meter was lowest for earth structures and under high rainfall. When using land clearing and compaction the cost was about 7 U.S cents per m^3 at average rainfall of about 625mm. This rose to 28 U.S cents at avarage rainfall of 150 mm. Costs of other treatments were much higher under similar rainfall.

It may be pointed out that the harvesting methods are site specific and before a system can be installed, the soil characteristics (water holding, infiltration, erodibility), topography (slope, surface roughness), precipitation characteristics (amount, reliability, intensity), and the climate should be known. In addition, factors such as land, labour and material costs, water use rate and distribution, storage requirement and its cost, water quality desired and availability of materials should also be taken into consideration.

None of the rain water harvesting methods has been subjected to a long-term economic analysis. Large field trials in different areas are needed to build up a data base that could lead to a better understanding of the economic viability of different methods in different economic environments. Developing countries particularly need the data, because of most of the technology was designed for Australia or the United States of America. With adaptive research to fit the needs, economic and materials of developing countries, rainwater harvesting methods may be of exceptional and immediate value. The majour technical research need is to reduce the cost of sealing catchment soils and to make the treatment practical for a wider variety of soils and situations.

MAXIMIZING PRODUCTIVITY PER UNIT OF WATER:

The increase of water use efficiency can be accomplished by the following techniques:

- Supplementary Irrigation in Rainfed Areas.
- Protected Agriculture.
- Genetic Engineering.

Supplementary Irrigation in Rainfed Areas:

Rainfed agriculture occupies about 70% of the cropped areas in the Arab World but it contributes only 25% of the total value of agricultural production. Recent research and pilot areas on supplementary irrigation in the region has demonstrated that the present yield of winter cereals (wheat and barley) in areas of 350 to 400 mm of annual rainfall, which is about 1.0 to 1.2 Ton/hectare, can be increased from 3 to 5 tons/hectare by the application of 150 to 200 mm of water as supplementary irrigation.[4] This means that the productivity of the water unit added as supplementary irrigation is about five times that of the rainwater. In addition to the increase in yield, the quality of the produce will also improve in term of flavour and marketability. This leads to the conclusion that supplementary irrigation should be used, wherever possible.

This practice is suitable for the use of harvested water, treated wastewater and low quality water, i.e., brackish water. Adding one to three irrigations of brackish water, as suplementary irrigation, at the critical time of the plant growth, will not cause the hazard of salt accumulation in areas with more than 350 mm of rain, because the latter will do the necessary leaching.

Protected Agriculture:

High agricultural productivity has been achieved with small amounts of water through the use of the controlled environment. The system consists of growing crops within watertight but transparent enclosures; the amount of water lost can be greatly reduced. The atmosphere around the planst which includes; heat, light, water, humidity, carbon dioxide, nutrients, and pests are manipulated and balanced to produce yields often more than ten times larger than those of conventional outdoor agriculture.[10]

In Jordan protected agriculture has shown that the production in green houses using good seeds and high inputs can produce yields of tomato and cucumber equal to 10 times or more of the open cultivation and using water of not more than 60% of the water used under open conditions. This means that the production under protected agriculture per unit of water is equal to about 16 times the production under open agriculture.

The use of mono or multispan enclosures, consisting of iron or aluminum frames covered with plastic sheets, or transparent fiberglass and low tunnels of plastic sheets supported by steel wires over the rows of the growing plants is being practiced in Jordan on large scale with good success. The only problem facing the wide spread of its use is the high initial capital investment, together with the marketing problems facing agricultural production in Jordan.

Genetic Engineering:

Only one percent of the water absorbed by roots is incorporated into plant tissues as 99% moves up through the plants and passes into the atmosphere as water vapour. This process called transpiration, differs from evaporation in that it takes place on living tissues and is influenced by the physiology of the plants. One hectare of growing vegetation can transpire as much as 100 m^3 per day. If practical way of reducing transpiration could be found without affecting the crop yield, a substantial reduction in water demand could be achieved especially in arid lands. Plant breeding to produce strains of high water use efficiency is needed.[10]

DESALINATION OF BRACKISH AND SALINE WATER

Desalting of brackish water from surface and ground water sources and from sea water offers inexhaustible sources of water for arid and semi-arid areas. At present the cost of desalted water from brackish water of 3000 to 10,000 ppm of salt content, using reverse osmosis process (R.O), which is the most suitable for desalting this kind of water, varies between 30 to 50 US cents per cubic meter. In case of sea water using either multi-stage flash method [MSF] or R.O. this cost varies from U.S. $1.00 to $1.50. In the absence of local fresh surface or groundwater sources, the desalination of brackish and salty water for domestic and industrial purposes is the only alternative for many locations in the Arab World.

Desalted water is one of the main source for municipal uses in some Arab countries. In 1995 the total desalted water in these Countries amounted to about 1960 million cubic meter which is equivalent to about 50% of the global production. Saudi Arabia alone produced about 800 million cubic meter followed by the united Arab Emirate of 385 million m^3 then Kuwait of 240 million m^3. (Table 3.).

Since the cost of desalination of brackish water is becoming feasible for its use for municipal purposes and the availability of such source of water, mainly as groundwater in many Arab Countries, who are facing, forthcoming severe water shortages, it should be the policy of such countries to give priority to the desalination program of brackish water to that of sea water.

The developments of the past twenty years have brought about significant changes in the science of desalting. The most important step, however, will be the transition to large-scale equipment and the use of atomic energy as a source of power for desalting water and electricity generation. But the rate of such transition will be governed by the policies of governemtnts, i.e., by commitments to develop new land which relies on desalted water sources, by water pricing policies and by subsidizing of the initial steps in the scale-up of units. In the next 15 to 20 years, we will begin to reap the fruits of our labour to make the deserts green and millions of people will face the future with new hope and confidence.

OTHER PROMISING WATER CONSERVATION TECHNIQUES

These include:

- Reducing evaporation from water surfaces.
- Cloude seeding and fog harvesting
- Reducing evaporation from soil surfaces.
- Reducing cropland percolation losses.
- Irrigation with saline water.
- Selection and managing crops to use low quality water and more efficiently.

The following discussion is, very brief summary of these techniques. Reference No. 10 could be consulted for more details.

- Because evaporation is invisible, it is seldom regarded as serious drain on stored water, but annual evaporation losses, are very great under arid condition. As an example, annual evaporation from lake Nasir is estimated at 10 milliard cubic meters. This is equivalent to nearly ten times the available water resources of Jordan. Hence evaporation reduction from the surface of water reservoirs merits increased attention as a way to conserve water.

- Cloude seeding, under certain conditions, can contribute substantially to the water resources of the country. Experimental trials in Jordan showed an increase of about 10% of annual rainfall. Syria has been conducting a cloude seeding program since 1992 and they claime an increase in precipitation of about 2.5 to 3.6 milliard cubic meter per year and with an average cost of U.S. $ 2.0 per 100 m^3.[(1)]

- Fog-harvesting work in Chile proved to be very useful in providing municipal water supply to isolated communities at a cost of about 30 U.S. Cents per cubic meter, which was very compatative compared to the prevailing cost of water in these localities.[(4)]

- Evaporation from soil surfaces can be reduced by cover or mulches. It is becoming a general practice to use plastic mulches over the drip irrigation system for producing vegetables in the Jordan valley. In addition of reducing evaporation losses, the quality of the produce is improved by having a clean and regular shaped products free from dirt.

- In arid regions there exist large areas of sandy soil not used for agriculture because the water sinks below the root zone too rapidly and the extra irrigation water needed to compensate for this problem is not available. Techniques are being developed to produce artificial underground moisture barriers to prevent or restrict water and nutrients from deep percolation.

- Brackish and saline water are widely available in Arid Areas but rarely used because they restrict plant growth and yield. Today, new appreciation of plant physiology and soil science and new irrigation techniques are showing that with careful management saline waters can be used to grow a variety of crops. At present a large scale agricultural project using sea water is being conducted at the east coast of Saudi Arabia.

- Most crops grown under irrigation use water in an inefficient way. Some crops may need 2000 kg of water to produce 1 kg of useable dry matter. Much research is needed for the selection and breeding of food, forage and industrial crops, specifically to use less water per unit of product, and to produce strains which are draught and salt tolerant.

DEVELOPMENT COST OF CONVENTIONAL AND NON-CONVENTIONAOL WATER SOURCES:

It may be of interest to summarise the cost of development of some of the above mentioned techniques for developing additional water sources.

- The cost of water in the development of conventional new irrigation projects is about one to 30 U.S cents per cubic meter.

- The cost of water in the rebabilitation of existing irrigation projects which involves lining of canals, improvement of structures and conversion of gravity surface irrigation system to pressurised system will be about 5 to 50 U.S cents per m^3.

- The cost of wastwater treatment varies between 20 to 50 U.S cents per m^3.

- The cost of desalting of sea water varies between U.S $ 1.5 to $ 3.0 per m^3 depending on the size of the unit and the process used. In case of using units of the capacity of more than 100 000 m^3/day the cost of water produced will drop to about U.S cent 70 to 80 per m^3 using either the multi-stage flash (MSF) or reverse osmosis (R.O) processes. In case of using brackish water of salt content less than 10 000 ppm, the R.O process is the best and the cost of m^3 of water produced will be about 25 to 40 U.S cents, depending on the level of the salinity in the water to be desalted and on the size of the desalination unit.

- According to the Syrian experience in their cloude seeding programm, during the last 4 years, the cost of water produced was estimated at 2 U.S cents per 100 m^3, the equivalent to 0.02 U.S cents per m^3.

- Fogharvesting in Chili showed that the cost of one cubic of water harvested was about 30 U.S cents.

It must be pointed out that the above figures are not strictly comparable. They are reported here to give some indications on the magnitude of cost of development of different water sources. Generally speaking it could be stated that in most cases the cost of development of certain volume of water throught the improvement of the efficiency of existing irrigation projects will be less than the cost of establishing new irrigation projects with the same amount of water. Hence, priority should be given to the rehabilitation of existing irrigation projects, together with the increase efficiency of water conveyance and application at the field level. Priority should also be given to the treatment and reuse of wastewater, not only on economical ground but also because of environmental and public health considerations. It seems also that cloude seeding offers a good possibilities under certain geographic and climatic conditions, as reported by the Syrian experience. Also not to forget the great potential of water-harvesting under arid and semi-arid conditions.

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