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IRRIGATION SYSTEMS PERFORMANCE IN JORDAN

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SUMMARY - The total irrigated area in Jordan is estimated at 76,000 hectares distributed between the Jordan Rift Valley (JRV) of 33,000 hectares and the highlands and the desert areas (43,000 ha). These areas consumes around 65% of all water uses in Jordan and 53% of the groundwater. Irrigation in the JRV is publicly managed irrigation systems and uses mostly surface water of the Yarmouk River and side wadies. Irrigation is supplied to the farm units through King Abdullah Canal and under pressure. Furthermore, there are around 195 private managed agricultural wells in JRV. In the highlands, irrigated agriculture is privately managed and uses groundwater wells as a water source, while the area in the desert is irrigated by fossil groundwater. The adoption of high tech irrigation systems (micro-irrigation) is increasing and has reached about 60% in the JRV and about 85% in the highlands. The use of sprinkler systems is limited to forage and cereal production and does not exceed 10%. The rest of about 30-40% are still using the traditional surface irrigation, mainly in the JRV. This paper discusses the performance of irrigation system in JRV and the highlands where two criteria are considered. The first criteria implies the uniformity of water distribution in the irrigated field and the second concerned with water application efficiency. Diagnostic studies have shown that the overall efficiency in the JRV valley was about 65% considering conveyance and application efficiencies. The on-farm irrigation efficiency in the highlands using groundwater and micro irrigation has been measured to be 85%. The performance of the center pivot systems in the southern desert has given the uniformity of water application ranging from 76 to 84% under different operating pressures. Realizing the urgent need to control agricultural water demand, the Ministry of Water and irrigation and the Ministry of Agriculture have initiated several projects and programs. The paper discusses some of these initiatives such as the Irrigation Advisory Services, Kafa'a project and the Irrigation Information System. The aim of these programs is to increase efficiency of water use, improve irrigation management practices and up grade design and evaluation capabilities.

Key words: irrigation, irrigation systems performances, irrigation efficiency, Jordan.

INTRODUCTION

Jordan is classified among few countries of the world with limited water resources where demands are far exceeding supplies. The total area of Jordan is about 89,400 km^2 where 92% of it is located in the arid to semi arid region. Most of the lands in this region are arable land if water resources can be made available. Water in Jordan is considered not only the main factor of production but also a very crucial factor of survival and social development. Comparing the volume of natural renewable resources of 940 million cubic meters (MCM) to the current population estimate of 5.48 million people (in 2003) would result in a per capita share of water of 175 m^3 per year. On the other hand, considering allocation of water for domestic and industrial purposes, the agricultural per capita share of water will be about 100 m^3 per year. This amount represents about 12% of the individual need for water to provide enough food and fiber.

At the present, the current annual water consumption is estimated at 935 MCM; 610 MCM of them are allocated for agriculture, 270 MCM are consumed for domestic purposes, and an estimated 65 MCM are allocated to industrial and other purposes. The amount of water consumed have been derived from different sources as: 520 MCM from ground water, 370 MCM of surface water and 65 MCM as treated wastewater. It is clear that water consumption is heavily dependent on groundwater where about 80 MCM of it comes from the non-renewable resources and about 440 MCM comes from

the already exploited renewable groundwater aquifers. The rate of abstraction from these aquifers is 160 MCM above their safe yield which is estimated at 280 MCM.

Surface water resources in Jordan comes from different sources such as the Yarmouk River flow, the flow of the side wadies, release of the dams, and the share of Jordan from River Jordan. Out of the 600 MCM as potential surface water only about 370 MCM have been utilized due to different reasons mainly the lack of enough storage facilities and the difficulty in catching desert floods.
This amount varies from one year to another depending on the amount of precipitation.

The topographic features of the country are variable with approximately 80% of the total area is steep mountainous or steppe arid land (Badia). Jordan can be divided into three distinct regions from west to east: the Jordan Rift Valley (JRV), the Plateau and the semi-desert or the Badia region. The Jordan Rift Valley is part of the Great Rift Valley where it runs from lake Taberia in the North to the Gulf of Aqapa to the south. Officially the area bounded by elevations of 400 m below sea level and 300 m above sea level is called the JRV. JRV contains the Jordan Valley north of the Dead Sea, the Dead Sea area, the southern Ghors south of DS and Wadi Araba which runs from the upper point of the southern Ghors to the Gulf of Aqapa. The Jordan Valley and the southern Ghors are the major irrigated area of about 33,000 ha with a potential of 43,000 ha.

The plateau is situated immediately to the east of JRV where its elevation varies from 300 m to about 1200 m. The plateau comprise of a narrow strip running north to south and varying in width from 25 to 40 km. Rainfed agriculture is practiced on the arable lands in the plateau with average annual precipitation of more than 300 mm. Irrigated agriculture can be found in limited areas where irrigation water is supplied from the base flow of the side wadis, springs or local wells. State and private forests can be found on the mountains and steep rocky land but they comprise only 1% of the total area of the country. The range land area of annual rainfall between 200 mm and 300mm represents about 5% of the total area of Jordan.

The remaining part of Jordan (about 90% of the country) is low rainfall semi desert area which is called locally "the Badia Region". Rainfall in the Badia region is sparse and erratic ranging from 50 mm to 200 mm and is sufficient to give a thin and occasional vegetative cover useful for short period of grazing.

In general, only 4% of the total area of Jordan can be put into cultivation through rainfed agriculture in years of sufficient rainfall. The actual cropped area is 306,000 ha in 2000 compared to 380,000 ha. Areas developed for irrigated agriculture amounts to approximately 76,000 ha. Of this total, 33,000 ha are in the Jordan Valley and the southern Ghors which are primary developed by the Government. The rest of the irrigated area of about 43,000 ha have been developed by the private sector in the plateau and the Badia regions depending mainly on groundwater.

IRIGATION DEVELOPMENT IN JORDAN

Historically, irrigation in Jordan was concentrated around springs and along river and wadi beds where the traditional surface irrigation was applied. Water distribution among farmers from these sources were managed by the farmers themselves. Starting early 1960s, the government of Jordan put high priority in development large irrigation projects starting by building the East Ghor Canal project (King Abdullah Canal). The water to this project has been diverted from the Yarmouk river and Side wadies. Later in 1970, the government decided to explore the desert by drilling wells around ground water aquifer for irrigation purposes aiming and social and economical development of rural and beduin population. In the late 1980s and early 1990s, the privet sector got involved in the development of ground water for irrigation either by individuals or through agricultural companies.

Accordingly, the irrigation projects in Jordan can be classified into two categories; first public irrigation projects in the Jordan Rift Valley and the irrigation in the highland and the desert. The total irrigated area in Jordan has reached 76,000 hectares distributed as 33,000 hectares in the Jordan Valley and 43,000 hectares in the upland and the desert.

Irrigation in the Jordan Rift Valley

The Jordan Rift Valley area extents from the lake Tabarieh in the North to the Red Sea in the south passing through the Dead sea. The area north of the Dead Sea is called the Jordan Valley while the area south to it is called southern Ghors and Wadi Araba. A major study for the integrated development of the Jordan Valley was conducted in 1953 (Baker and Herza, 1953) for the development of the land and the water resources in the Jordan River System. This study showed that it would possible to put under irrigation an area of about 360,000 dunums (36,000 hectares) in the Jordan Valley. As of 1957 the government of Jordan began implementing the study at different stages. But due the abstraction of the flow of the River Jordan and its tributaries, the above figure was never achieved. The area which has been developed and could receive irrigation water is 230,000 dunum plus 60,000 which has been equipped by irrigation distribution system but no water allocation. The irrigation development during this period include building a main canal with a head capacity of 20 m^3/s in addition to a diversion weir on the Yarmouk river and a 3 km tunnel. The canal length has reached 110 km. Most of the secondary distribution conduits are pressurized laterals equipped with pumping stations along the canal while others use the natural heads from the Dams. Other major development activities accompanying the implementation of the plans were the construction of five dams with a capacity of 160 MCM. Future plans include the construction of Wahda Dam on the Yarmouk River with a capacity of 225 MCM and utilizing of about 20 MCM of the treated effluent in a closed area north of the Jordan Valley. Works on improving the conveyance and diversion efficiency of the side wadis are in progress

The main concern in the Jordan valley is the decline of the available water resources due to drought, upstream uses and the overuse of groundwater in the tributaries basins. The available resource has dropped from an average of 370 MCM per year during the last 2-3 decades to about 250 MCM per year during 1997-2000 period.

Irrigation projects in the southern Ghors utilize the base flow of the Dead Sea side wadis by regulating their flow through construction of the weirs and irrigation canals. At the first stage an area about 48,000 dunum were put under irrigation. After construction two major dam, the irrigated area in the second stage will reach 63,000 dunums. There is a potential to irrigation about 20,000 dunum in Wadi Araba using the groundwater resources in that area.

Irrigation in the Upland

In the late sixties and early seventies, the government began developing pilot projects in the desert and the upland of Jordan using groundwater. The expansion in irrigation began in eighties and early nineties by the private sectors through utilizing the groundwater. These activities concentrated on the major basins of Azraq, Amman-Zarka, upper Yarmouk, and the Dead Sea basins. The uncontrolled pumping from these aquifers has exceeded their safe yield to about 150%. The irrigation activities have also been extended to utilize the non-renewable resources of Dissi and Mudwarah area where about 70 MCM are being pumped annually from the aquifers and are used for agriculture. Recent studies have estimated that it would be possible to pump about 120 MCM annually from the non-renewable aquifers of Dissi for about 100 years.

The total irrigated area in the upland and southern Desert has reached 43,000 hectares according to the Ministry of Agriculture estimates.

Irrigation Systems

Jordan Valley irrigation project is a public scheme controlled and managed by Jordan Valley Authority (JVA). Jordan Valley Authority was established by law (JVA law 1977) and is responsible of land and water resources development in the Jordan Rift Valley. After land reform, the land under irrigation is divided into farm units of 3-4 hectares each. Each farm unit is provided with water through farm intake. Water is conveyed from different source through the main canal (King Abdullah Canal, KAC). For more the 90% of the area, water is delivered to the farm in a pressurized pipe laterals. Pressure head is provided from pumping stations adjacent to the main canal or using the natural head of some dams at higher elevation

Jordan has witnessed rapid evolution in the adaptation of high tech irrigation systems since 1980. Perrier to that , surface irrigation was the dominant system in the Jordan Valley and around the springs. According to the Jordan Valley Authority(personal communication), surface irrigation occupy 30% of the irrigated area in JRV while micro irrigation has reached 68%: the remaining 2% is irrigated by sprinkler systems. This development has increased due the complete convergence of the water distribution into pressurized pipe network.

The situation in the upland is different since most of irrigation water is pumped from ground water aquifers. The irrigated area here is privately owned and managed, therefore about 85% of area is under micro irrigation while 10% of area are using sprinkler irrigation mainly center pivot. The traditional surface irrigation represent only 5% which is concentrated around springs and the beds of side wadies.

IRRIGATION SYSTEM PERFORMANCE

Introduction

Nearly 74 % of the drip irrigation system were designed and installed by farmers in Jordan, while 26% were designed by irrigation companies and specialized professionals. The high degree of systems designed and installed by farmers may contribute to some of low efficiencies that prevail in the valley. Professional assistance may be of value to help realize efficiency gains. Similarly, only 10 % of the farms depend on specialized irrigation professionals to operate their systems. In general, farmers were satisfied with the availability of repair services and spare parts for high-tech system.

In the JRV most farmers (55%) had a reservoir on their farms, but only 31% had pumps. Instead of using reservoirs, 46% of farmers connected their drip irrigation systems directly to Jordan Valley Authority pressure lines. About 90% of the drip irrigation systems use in-line emitters (G.R type) in 16-20mm-diameter laterals; these can deliver 3-4 liters per hour. Emitter clogging was a considerable problem for farmers. Most of farmers had filtration units (sand filter, a screen, or both). Filters were cleaned frequently, sometimes each hour of irrigation. Field research was carried out on farms representing irrigation types and crops that are typical of the central Jordan Valley;

Efficiency of the Jordan Valley Irrigation System.

A study on The water balance for the Jordan Valley Irrigation Project for the years: 1979, 1980, 1981, and 1982 showed that the efficiency of the conveyance and distribution system was ranged from 70 to 94 for the five years (Shatanawi, 1987).

Performance and efficiency of center pivot irrigation systems in the southern desert of Jordan.

Nazzal and others (1989) evaluated the performance and efficiency of center pivot irrigation systems in the southern desert of Jordan. They found that uniformity of water application under different operating pressure heads and speed settings ranged from 75.5 to 84%.

Irrigation Management and water quality in the central Jordan Valley (Winter cropping season – ISPAN, Shatanawi, et al 1994).

A field research was carried out on farms representing irrigation types and crops that are typical of the central Jordan Valley during the winter season. Water applications were compared with crop evapotranspiration to compute on-farm irrigation management efficiency(IME). IME is the ratio of water beneficially used by a crop (crop evapotranspiration) to the total amount of water applied:

$$IME(\%) = \frac{Cropevapotranspiration(Etc)(mm)}{Waterapplied(mm) + effective.precipatation}$$

The results of this study were summarized in Table 1 .

Table 1. On-farm irrigation management efficiency in the Central Jordan Valley

Irrigation System	On Farm Irrigation Management Efficiency (%)
Surface Irrigation	70
Drip irrigation (open field)	56
Drip Irrigation in plastic houses	42

Two main conclusions were drawn:

1. For drip systems IMEs are very low. High-tech systems are operated at 56 % efficiency or less, offering much scope and opportunity to improve the performance of these systems. Improvement in IME will enable farmers and the country to increase cropping intensity and save water to irrigate additional lands.
2. The conventional method, that surface irrigation methods are inefficient when compared with high-tech irrigation methods, is incorrect. Drip irrigation has the potential to be very efficient. However, realization of the potential can occur only if systems are well designed and maintained, and if irrigation scheduling is in accordance with crop water requirements. If management is lax, and it has been, drip irrigation methods become very inefficient.

It is not surprising that drip irrigation plastic house are less efficient than drip system in the open field. Crop evapotranspiration in a plastic house is less than crop evapotranspiration in the open field because the high humidity in plastic houses retards evapotranspiration. Yet most farmers with plastic houses schedule the operation of their drip systems identically to a drip system under open conditions.

It is important to note that IME results are for the winter season only. Water is abundant in the winter, relative to summer. Because water storage facilities are lacking, the Jordan Valley Authority permits winter water delivery in excess of crop water requirements. The excess water applied in the winter leaches salts from the soils and permits cropping of salt-sensitive vegetables. It is difficult to estimate how much leaching is necessary.

Jordan has invested heavily in pressurized conveyance and delivery systems that permit farmers to convert to potentially efficient on-farm drip irrigation methods. However, parallel investments have not been made to upgrade older drip systems or to train farmers new to drip systems in how to operate and maintain these technologies. 68 % o the Jordan Valley is now drip irrigated while 30% is surface irrigated and only 2% is sprinklers irrigated (personal connection,). Additional attention must now be paid to improve the management of on-farm systems and thereby increase their efficiency. Unless Jordan commits to further investment in on-farm water management, the benefits from conveyance and delivery improvements cannot fully realized.

An estimate of economic returns to water use under the three types of irrigation technologies in this study is given in Table 2. The economic returns to water use in plastic houses are almost 50 times of those of the surface systems and more than 15 times those of drip systems in open field.

Table 2. Economic returns to water use in the Central Jordan Valley

Irrigation System	Economic Returns to Water Use
Drip Irrigation in Plastic Houses	JD 1.260/m^3
Drip Irrigation	JD 0.0780/m^3
Surface Irrigation	JD 0.028/m^3

The obstacles and challenges facing the irrigation management

A study was curried out by the NCARTT on irrigation system performance in the Jordan Valley in 1999. The results show the following:

A. 70% of farmers installed their irrigation system by themselves;
B. The on farm irrigation efficiency ranged from 39.37 to 78.2%;
C. The most important problems for farmers are: emitter clogging 45.5%, water shortage 18.2%, irrigation system managements 9.1% and other problems are related to errors in irrigation system design;
D. The main reasons for changing the traditional irrigation system to drip irrigation are: saving of water 37.5%, increase of the yield 25%, easy to deal with the system 25% and to change the crop 12.5%.

The solutions suggested by this study are:

1) Good irrigation system design and management;
2) Irrigation scheduling management (using soil moisture tension instruments and the metrological data for estimation of evapotranspiration);
3) Using fertigation system;
4) Selection of suitable filtration system;
5) Operation and maintains of irrigation system.

MEASURES TO IMPROVE SYSTEM PERFORMANCE

Measure taken be Jordan Valley Authority

The following measures on the supply and demand sides have been taken by JVA to increase water use efficiency:

A. Building of Karameh Dam. This dam is being constructed at Wadi Malha, to the west of Karameh in the Jordan Valley, with an estimated construction cost of about 52 million JD. This project that started in 1994 and completed in 1997, will yield about 35 MCM/year for agricultural use.
B. Raising of Kafrein Dam project that, completed in 1998, would increase the capacity of the existing dam by 4.6 MCM.
C. Irrigation Water Delivery Scheduling Pilot : under this pilot programme, farmers will be able to order water for delivery any day and in any quantity, up to a set maximum, throughout the crop season. The total quantity of water used for a crop will not change from current levels. The aim of this pilot is to give farmers more control over their water delivery schedules. This benefit comes with more responsibility. Farmers become responsible for keeping records of water application amounts and must determine application times and quantities for irrigation.
D. Repair of canal linings along the northern 94 km of King Abdallah Canal (KAC) which has been completed in 2000.
E. The automated water management control system of the Jordan Valley, financed by KFW, consists of three phases. Phase I started in 1985 and ended in 1988. This phase included the computerization of the irrigation management system and data bank. Phase II started in 1988 and ended in 1991. The activities of the second phase included the updating of Phase I hardware to meet additional requirements, and the development of new hardware. The automated water management control system is being applied in the Jordan Valley, a pilot project started in mid-November 1994 and will continue in order to adopt the automated water management programmes. A parallel project, financed by KFW, was launched with the interim phase to implement a Water Measurement Network along KAC, including the installation of 14 Measurement Stations and the automation of four Check-Gates. The contract for the studies and supervision of this project was awarded to GERSAR (a French firm) in association with local firms SMS-QUBEIN-TAG ENG. The Measurement Network will be expanded later on to cover all the water resources in the Valley.
F. Since the horizontal expansion is limited, increasing cropping intensities in wet years are being considered by the farmers in the valley. The Jordan Valley Authority is encouraging the farmers for intensive winter cultivation.
G. Due to the limited water resources and water quality constraints, the cropping pattern of new projects will be directed towards the use of salt-tolerant crops like dates, and semi-tolerant

crops like early producing seedless grapes which offer good net income. A good example of this is the area to be irrigated by the Karameh Dam water and the planned irrigation projects of Wadi Araba.

H. An on-going USAID-financed project (WQICP) is being carried out under the administration of the Ministry of Water and Irrigation. One of its components is to deal with research and extension of the farm water arrangement.

I. A GTZ-financed study, carried out by GITEC and CEC (1994), study for the Recovery of Operation and Maintenance Costs of Irrigation Water in Jordan, was completed mid-1994. As a result of the study's recommendations, a new tariff for irrigation water has been adopted since 1995.

Water saving Pilot projects

TO2 Pilot project

In 1998, the JVA has suggested to concentrate the proposed studies of possible network and ‘’on farm’’ management improvements in a pilot area in the TO2 Adassyeh area (131 farm units - 400 ha). The main proposals were :

a) Use pipes of adapted diameters - A correct of on-farm network requires a technical study (simulation program, hydraulic calculations);
b) Use the micro-spray/virojet irrigation systems for citrus;
c) Use screen filters for micro sprays systems - in order to limit the labor to clean the emitters to assure always the same flow and wetted area;
d) Improved screen filters - modified local screen filters with bigger filtration area to extend the operation period
e) Training of the farmers on pressurized network operation
f) Control of the illegal openings How to maintain the ditch riders control, how to limit the corruption risks ? How to use the farmers to support the control by the ditch riders. How the fines based on daily water-meter readings can be continued and extended?
g) Possible extension to the vegetables areas where the farmers use already pressurized “on farm”’ irrigation systems with pools and individual pumps - the proposals may be different (better design of the networks, better filtration, cover the basins to control algae’s, smaller flow rates but receiving water during longer periods, increased period of direct use of JVA pressure,...).

Kafa’h Project (3-5 years duration)

This project has been implemented by the USAD, Jordan Valley Authority, Ministry of Agriculture, National Center for Agricultural Researches and Technology Transfer, (NCARTT), Universities and other public and privet sectors. The Project has started in December 2003 in the Jordan Valley and Amman-Zerqa Basin with the following objectives:

a) Improved water resources management;
b) Initiate a long-term program of water-use efficiency in agriculture.

Project activities:

a) Advise decision-makers of unassailability of present practices in water/ agriculture sectors. Build constituency and advocacy for agriculture water conservation policy.
b) Provide farmers with information
c) Demonstrate improved on-farm water management practices to poor, rural communities.

Performance goals of the project: significant spread of new attitudes and behavioral patterns among the Jordan Valley and the Amman- Zarqa farmers.

Anticipated results:

- At least 80% of farmers in the project area are familiar with on-farm water management techniques;
- At least 30% of farms in the Jordan Valley and Amman-Zarqa basin irrigating with wastewater effluent have adopted cropping pattern;
- At least 50% of farms in the project area have adopted water-efficient irrigation technologies and 60% of farms have improved on farm water management practices;

- The water use of 50% of the farms in the project area has decreased by an average of 10%;
- Average productivity in at least 30% of the farms has increased by 5%;
- Income of 40% of farmers has increased by an average of 15%;
- A mailing list of farmers in Jordan is developed;
- At least 5 demonstration sites exhibiting techniques and methods of improved irrigation water management established in the Jordan Valley and the high land.

Conversion of open irrigated canals to pressurized pipes in Jordan Valley.

This project started in 1978 in which all open canals in the northern and central part of the JV were converted to pressurized pipes connected to the farmers fields. The main result of the project was reducing all losses related to leakage and evaporation and the disruption efficiency was increased from 65% to 90%.

The Jordan Valley authority now working on converting all conveyance and distribution net work to pressurized pips and the result of that will reduce 15-20% of total water applied.

Soil conservation and land leveling project

This project started in the beginning of 1960s by which 3000ha were leveled in the northern part of JV and 6000 ha in the southern part of Jordan. The project raised the surface irrigation efficiency from 40% to 70% and also reduced the labor cost and facilitated the irrigation design and management.

High- tech irrigation systems and management transfer

A. Introduce high-tech irrigation system - using the drip irrigation system increased the farm irrigation efficiency by 70-80%;
B. Irrigation scheduling and fertigation management transfer on farm level - The project started in the beginning of the 1990s, and it is implemented by the University of Jordan and the National Center for agricultural Researches and Technology Transfer in cooperation with international organizations. The project introduced a technology for determination of water application and time of irrigation. The use of this technology in the project has allowed for water saving from 40 to 60% of irrigation water requirements, an increased fertilizer application efficiency and increased the yield quantity and quality.
C. Irrigation scheduling and water management on farm level - This project was applied in the northern and central part of the JV. The computerized electronic control was used for supplying of irrigation time and quantities to agricultural basin (group of units) depending on the crop type and the planted area. The distribution efficiency for the irrigation networks increased by 20-25% with reducing labors cost.
D. Determination of actual evapotranspiration and crop coefficients for vegetables grown under plastic houses in the Jordan Valley - This project started in 2000 by the NCARTT in the central Jordan Valley. Main vegetable crop which grown under protected conditions were studied. Using the project results will save more than 50% of irrigation water comparing with actual farmer practices.

Irrigation Management Information System (IMIS)

This project was started in 1997 by NCARTT to archive the following objectives:

a) To establish and develop a metrological and agricultural data bas for water management and irrigation scheduling .
b) To develop and prediction of modeling and theoretical equations for crops water consumptive use determination.
c) Establishment of crops irrigation program in the Jordan Valley.
d) Training of the irrigation engineers on using the metrological data and transferring it to the farmers.

Four metrological stations were installed in the following locations:

a) Sharhabeel Station (Northern part of Jordan Valley);
b) Deir-Alla Station(Central part of Jordan Valley);
c) AL-Karamih Station(Southern part of Jordan Valley);
d) Muro Station (high land).

All of these stations were connected to the main NCARTT office. The JVA and other researchers were using these data for water distribution in the Jordan Valley.

CONCLUSIONS

Jordan Valley farmers, private industry, the Government of Jordan, and donating agenecies share a common interest in seeking to increase the use of drip irrigation methods in the Jordan Valley. Increased use of drip irrigation methods should advocated because drip irrigation has the potential to be highly water efficient. However, the ISPAN baseline shows that drip irrigation systems, as currently operated, waste more water than do conventional surface systems. The new initiaties adopted by the MWF, Universty of Jordan and NCARTT offer the opportunity to work with farmers, industry, and government officials to make the change from low-efficiency to high-efficiency drip irrigation.

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