Irrigation Optimization in the Jordan Valley: Main lessons learnt (2000 - 2004)

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Abstract

In a context of water scarcity, the optimization of water use in agriculture is essential. In the Jordan Valley, the Jordan Valley Authority (JVA) is managing the water resource. Both JVA and farmers have greatly improved their techniques in the past decades. Nevertheless, many improvements, both technical and organizational, can still be achieved to optimize irrigation in the Jordan Valley. Therefore, in cooperation with JVA and farmers, the French Mission for Agriculture and Water has been demonstrating in pilot areas how improvements of water management are possible. At the level of the JVA network, an equal distribution of water among farmers has been the main objective. This requires ensuring the same flow, pressure and quality for each farmer. In parallel, on-farm techniques and methods improving the efficiency of water distribution have been demonstrated, then adopted and developed by many farmers.

Introduction

The French Mission for Agriculture and Water[1] has initiated in 1997 in the Jordan Valley, organized demonstrations of tensiometric scheduling of irrigation. At the same time, another French team[2] was working with the Jordan Valley Authority on the installation of a telemetric management for the King Abdallah Canal (SCADA = centralized control of the operation of the canal, dams and pumping stations).
In 1998, the necessity appeared to also study, in collaboration with JVA, the questions raised about the distribution of water from the canal to the farms.
Since then, the IOJoV[3] project aims to demonstrate, in the field, how improvements are feasible and actually effective, not only on the on-farm results, but also at the level of JVA water delivery.
We will present the main lessons learned and our proposals for an improvement of the current situation, initiating with the JVA networks management, and then presenting the questions raised on JVA water allocations. We will finally deal with the possible on-farm improvements.

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[1] French Mission for Agriculture and Water = Mission Régionale Eau et Agriculture (MREA)
[2] From SCP (Société du Canal de Provence)
[3] IOJoV = Irrigation Optimization in the Jordan Valley

1. Improvement of the "JVA network" management

We define the JVA network, as from the intake on the canal until the FTAs[4]. The management of this network includes:
-the operation of the pumping station to deliver to each farmer his water allocation, including the control and the measurement
-the maintenance of the network and its machines and devices
-the definition of JVA allocations
Currently, all these tasks need to be greatly improved, due to the actual inefficiency and inequity of the distribution. The changes we proposed are not only technical, but concern also the organization and the content of JVA water delivery service.

1.1 JVA hydraulic network operation

1.1.1 Identification and description of the problems

Pressure and flow problems

Basically, JVA should provide all farms with standard flow and pressure, whatever the on-farm system. Considering the network characteristics, this optimal situation is hydraulically conditioned by a high pressure in the lines, coupled to a low flow-demand at each FTA, which should be independent of the headlosses inside the farm as well as from the pressure itself (in a certain range of pressure).

But these two conditions are generally not gathered in JVA networks.
First of all, this is due to a modification of the original networks design. Indeed, the pressurized networks had been initially dimensioned for a FTA flow-demand of 6 L/s for a 3,5 hectare (35 dunums) farm in average. This low flow could not fit with the surface irrigation, still wide-spread at that time, but was supposed to be used with more efficient on-farm systems, like overhead sprinklers, micro-sprinklers, drippers... Therefore, under the pressure of farmers, all the flow-limiters inside the FTAs have been replaced by new flow-limiters of 9 L/s and even sometimes of 12 L/s, when demand is high (bananas).

Then, the rotation schedule[5] is not hydraulically optimized. Indeed the rotation schedules are not based on hydraulic calculations, but must comply with means of transport of the ditch-riders, because they are responsible for opening and closing the FTA valves, and with farmers' requests. This produces often situations where lines convey flows higher than their capacities. This induces high headlosses and the resulting pressure at the level of FTAs is strongly decreased.

Another factor which disturbs the repartition of the flow, by increasing the demand flow, is the illegal openings which increase strongly the headlosses in the lines.

[4] FTA = Farm Turn-out Assembly. It gathers a gate valve, a water-meter, a flow-limiter and sometimes a pressure-regulator, all protected by a closed concrete box.
[5] the distribution along the lines of the FTA open at the same time

The bad distribution of the flow is further deteriorated by the fact that, in an attempt to limit the illegal openings, only parts of the JVA distribution network are operated at once: main gate valves on sub-lines are kept closed so that only half of the network is pressurized.

Finally, the operation of the pumping station has also a strong impact on the delivered pressure. Indeed, the volumes delivered at each turn-out are monitored by the SCADA system and operators must not pump more water than allocated. As a result, they tend to use the main valve to limit the entering flow, in case of illegal openings. The result is first that, they create more headlosses and diminish further the pressure, and second that they damage the valve itself (Because this valve is not supposed to be used this way, it quickly produces leakages, and then needs to be replaced).

The lack of control of the operation of the JVA networks

As quoted earlier, there is no hydraulic control of the rotation schedule suitability.
Furthermore, there is no checking on the pressure and flow actually delivered to farmers. So, on one hand, there is no way for the farmer to know if he actually received his allocation or if he can connect his networks directly to the FTA without pressure problems.
On the other hand, there is no way for the JVA to check that the service they deliver (pressure and flow) is suitable. Furthermore, because many water-meters are not working, JVA has often no means to check if the farmers have finally received their allocations, more or less, and they base the billing on their estimate of hours count and on the theoretical flow at the FTA. Even if the water meters are working, the reading is only monthly, which can not prove if the farmer respected or not the weekly rotation schedule and does not allow an immediate reaction to the illegal behaviors.
As a result, the control of illegal openings is really insufficient. The responsible FU is only detected after a huge delay (if detected). And even if the stealing can be detected on the Pump meter (because the delivered flow over-passes the ordered flow), ditch-riders have almost no means to go, find and red-catch the illegal opener.

The water quality problem

The water content of suspended solids endangers the watermeters by clogging them or damaging the propeller. However, the monitoring of the suspended solids in water is ignored or neglected: the ditch-riders and operators do not feel concerned by this problem.

At the pumping station:
- The trash-rack mesh is too wide and does not stop the floating materials, except the very big ones.
- The JVA staff does not drag the suspended materials from water surface, in the settling paths: plastic bags, polystyrene. On the contrary, the JVA workers profit from the basins to grow fishes, a share of which die and get added to the rest of the polluting solids. They neither clean the walls of the basins on which shells grow.
- The well (where water is pumped): sediments that accumulate there, result from the settlement during the night of the solids suspended into water, even the finest (clay, silt). The well is cleaned out manually, maximum twice a year. In-between, very

often, the deposits get flushed into the gravity line, even if there is a drainage system, which is of course harmful for the concerned farm units.
- It happens also that in a few Turn-Outs (like TO 2 and TO 41), there is neither a gravity line nor a drainage system. As a result, the quantity of sediments which accumulate between two cleanings is huge. In TO 41, the situation is worsened further by a bad design of the pumps, which are placed very low and are therefore very close to the mud level, even sometimes immerged in it.
- Then the well has been clean, it is re-watered and many types of sediment are suspended, but the staff does not always wait the sediments to settle to re-start the irrigation.
- The rotating screens are not working properly: not automated, lack of flushers... There are even doubts about the efficiency of their conception: After their installation, JVA has been obliged to place additional rubbers and we still suspect other possibly remaining leakages, because solids (plastics, polystyrene) are still found in watermeters, or block the FTA water-meters.

In the network:
-there are normally endings and low-points along the lines, where these can be flushed. Due to water stealings, these points have been either sealed or buried. Therefore, no flushing has taken place in the last decade. The sediments that accumulated induce additional headlosses, as well as polluting the water for the farm units at the end of the lines, especially in the Zhor.

1.1.2 Experimented and proposed Solutions

To improve the rotation schedule

The first step is to improve the distribution of the open FTAs in the network. But if FTAs are too widespread, it becomes impossible for ditch-riders to open and close the valves. So farmers must be delegated this responsibility, thanks to a private valve placed immediately after the FTA, whereas the gate valve inside the FTA stays open all the time. To check that they perform this properly and at the right time, the JVA has to:
-make a comprehensive weekly reading of the FTAs water-meters, for the respect of the number of hours;
-monitor and register the pressure & flow at the pump, for the respect of the schedule.
Finally, the networks should be again operated entirely; to favor further the wide spread distribution of the FTAs. It would also decrease the flow conveyed per each line.

To reduce the demand flow at FTAs and to allow a higher number of FTA to be open at the same time, all flow limiters should be comprehensively shifted to 6 l/s.
This change favors also the fight against illegal openings: less FTAs to watch, lower impact of stealing.

To optimize and ratify the rotation schedule, the use of hydraulic computerized models[6] should be generalized. This means first, for each Turn-Out network, to build the model of the entire network, then to calibrate it (measurement of flows and pressures for a given rotation schedule), and finally to test each rotation schedule that had been previously established upon farmers requests. This should avoid situations where requests from a few farmers damage the situation of all others.

To monitor and control the water delivery: a systematic check of delivered water quantity, pressure and quality

All the changes quoted earlier decrease further the feasibility of a visual watching of illegal openings. They are fully conditioned by the parallel use of the water metering. Therefore, all watermeters need to be working, visible and protected.

The FTAs need to be improved by:

-window on the FTA cover, allowing anyone to see the device: This allows not only the ditch riders but also the farmers to see the watermeter. When these realize that they can also use the water-meter as a tool to check if they receive the due flow and quantity (then claim to JVA if necessary), they will stop damaging the device.

-reinforced protection: renewed locks, sealed steel wire on flow limiters and watermeters, watermeters moved towards the center of the FTA (to avoid easy lateral access), clogging of the lateral openings. Indeed, farmers should not have any physical access to the devices inside the FTAs. Not only for avoiding vandalism or manipulation, which are very developed and sophisticated nowadays, but also to have the possibility to cut the water arrival, in case of penalty, without the farmer being able to re-open the JVA valve.

-fittings for pressure gauges: JVA should regularly assess if they deliver an appropriate pressure, by regular readings both at the pump and at the FTAs. The measure of pressure at the FTA is not only a way to assess the quality of the service delivered to farmers, but is also a mean to calibrate the hydraulic models or to check if a flow problem can be assigned or not to the flow-limiter or even to detect a leakage or blockage in the main pipes.

New "high-tech" tools could also be introduced to monitor pressure and flow in the entire network, and to monitor their evolution on a period of time: CDL, ultra-sonic water-meters. Both these tools are removable data loggers.

To monitor all the hydraulic problems and to register properly all the operations, especially in which concerns hydraulic modeling of the networks, it is necessary to have at least one trained technician in each stage office.

[6]EPANET is one of the available softwares, it has been developed by EPA (Environment Protection Agnecy)

Further solution to the water quality problem:

The pumping station design could evolve. Pilot project could test media filters instead of rotating screens. This would prevent any leakage for any thin but large elements like plastic sheets, polystyrene, shells, fishes, feathers... because it seems, from findings into watermeters and from farmers' sayings, that the impermeability to these clogging elements of the rotating screens is not 100%.

Definition of new tasks for the local JVA staff: operators, ditch riders and guider

The changes introduced into the operation of the network imply that the tasks of JVA staff have to evolve.
We proposed the following distribution of the work:

OPERATOR
-Monitoring and daily maintenance (greasing) of different filters and gates + Reporting to the guider in case of any problem
-Keeping clean the settling basins by a monthly deep cleaning, completed by the daily dragging of all floating devices.
-Watching and registering regularly the pressure and the flow at the pump, to detect not only any technical problem concerning the pump itself, but above all if the rotation schedule is respected or not.
- If there is an illegal opening, the operator has to inform the guider immediately. He MUST ABSOLUTELY NOT use the main valve to try to limit the delivered flow.

DITCH-RIDER
-Comprehensive weekly reading of water-meters
-Patrolling to watch farmers opening and closing on time and to observe if there is a need for maintenance (for example, concerning the security of the FTAs)
-Regular checking of the actual pressure and flow at the FTAs
-Reporting all this information to the guider
-Flushing of the endings and low-points on monthly basis and making sure that they are always clear and locked.

GUIDER
-Gathering, organizing and registering all the information
-Organizing the ditch-riders' work. For example, if the operator detects a too high flow, he sends a ditch-rider to go and watch.
-Analyzing water-meters readings and reporting to the directorate (including a list of who should be fined).
-Communicating to the maintenance teams, the weekly maintenance report and registering which maintenance has been done and what still needs to be done.
-Controlling the work of the operator: readings and water quality monitoring

Building capacity of the JVA staff

The local JVA staff lacks severely technical means. This affects very negatively the extent to which they can perform their work properly.
Each pumping station should be equipped with:
-Several small motorbikes

-A mobile telephone and a fixed telephone
-A computer for proper data treatment, registration and organization.

All JVA workers lack technical training. They have to be taught basic hydraulic knowledge, as well theoretically ("why changing the rotation schedule?", "why monitoring the flows?") as practical ("how to use a calculator?", "how to measure the flow at any water-meter?"). In addition to this, the operator and guider should acquire computer skills.

Transparency of the operation and systematic water users' participation

By distributing water to farms, JVA is supplying farmers with a public service. If this service needs very necessary improvements, farmers have to react and, in a way, force JVA to change.
As a first step, JVA should be completely transparent in its management and put at the disposal of farmers all the information concerning their network: Announcement of any change in the regulation, Irrigation schedule, Announcement of extra-hours, List of the fines, Work plan of the pumping station...

On the other hand, farmers should organize themselves to become a real counterpart of JVA. The delegation to the farmers of the responsibility to open and close the valve was the first step of the farmers' participation into water distribution management. The second step is what is nowadays developing in the Jordan Valley. Farmers get organized, sometimes in official water users associations, to initiate working with JVA on their common problems. This participation is a way to facilitate and improve the work of JVA, but it is also a way for farmers to become a real counterweight in JVA's decisions
For the future, it could be imagined that the JVA transfers to the farmers themselves a share of the responsibilities concerning the distribution of water inside the network, essentially the basic tasks of the ditch-riders: control of the correct repartition of the water between farmers, billing, fining, and reporting to the pumping station needs for maintenance or improvements.
The final step could be that JVA transfers to the farmers the ownership of the network, so that they would become completely interested into its management and conservation. This would go along with the development of private services, for maintenance for example, for which the farmers would pay themselves.

1.2 Maintenance of the JVA network

1.2.1 Identification and description of the problems

Insufficient number of workers in the field

The number of maintenance teams in the field is far too small and does not allow them to visit more than once per month each pumping station. This is mainly due to the low number of vehicles.

Insufficient means and training

We have already quoted the lack of vehicles. We could also quote the lack of basic tools. (For example, MREA has been requested basic stop-watches!)
But the more acute lack concerns the means to repair the devices. The example of the water-meters is serious and representative: there are no spare parts, for any of the water-meter parts. If a tiny plastic part of the mechanism is broken, the maintenance has to change the entire device! The maintenance workshop is thus full of old water-meters, partially broken, which may constitute a stock of second-hand spare parts...

On the other hand, the insufficient knowledge of the JVA workers leads them sometimes to deviating behaviors. The example of flow limiters is representative: when the team installs a flow limiter, they knock on the hooks, in order (according to them) to prevent the device to get clogged. Thus they damage the device and its hydraulic characteristics. And when they want to repair a flow limiter (for example because it is delivering a flow very far from its nominal), they try to put these hooks in their first position by knocking again. But without the calibrating device, that they lack, it is somehow impossible to re-establish the proper situation.

As a result: the degradation of JVA material is going on.

In JVA networks, even in the Northern Jordan Valley, a high share of the FTA watermeters is generally not working, simply due to the absence of maintenance, but also to vandalism. In such a situation, the billing is based on a theoretical flow and on a theoretical number of hours.

The same happens for the flow limiters. Some farmers damage their flow limiter to get a higher flow.

In the pumping station, as well, leakages are very frequent. It is also frequent that fragile and hidden pieces are simply lacking, like the flushers of the rotating screens.

The maintenance is so limited that there is actually no prevention. It can happen for example that stones or other large solids enter the lines during works. It can clog the entrance of one FTA and destroy the pressure at this farm. If there is no detection of the problem, by any measurement campaign, the situation can stay like this a long time.

Poor organization / communication between the different teams

The sharing of the responsibilities is not always clear, between the operators, the ditch-riders, the maintenance team of the directorate, the maintenance team of Fannoush[7]. So, certain tasks, especially concerning the pumping station, are finally neglected. For example the everyday greasing of some pieces of the rotating screen: the Fannoush team is responsible for the pump, but this should be considered and an everyday operation and be delegated to the operator, who ignores it completely for the moment.

[7] Fannoush is the main maintenance center in the Jordan Valley, taking care of the devices of all the JVA pumping stations.

Furthermore, there is no real organization for passing the information between those who detect the problems and those who are supposed to fix them: when the maintenance arrives in the network, there is no list of the problems, because there has been no written registration before. Thus the team can leave without having done anything, even there are necessities.

1.2.2 Experimented and proposed Solutions

The detection of the problems

In the pumping station, the operators should watch and signal any problem concerning the filters, the valves, the pump, but also automation disorder.
In their regular patrols through the network, the ditch-riders should watch and register any problem, like non-working water meter, leakage, broken cover, broken lock...
They should also make some regular pressure checking in the network, thanks to FTA pressure fittings, to detect unexpected pressure drop, which could be due to a clogging of the lines or to an underground leakage.

Through the analysis of the weekly water-meter readings, it is also possible to detect water-meters which work abnormally. In such a situation, the guider should send a ditch-rider to confirm by measuring pressure and flow at the concerned FTA. Regular measurements of flow could also indicate if flow-limiters work correctly.

The optimization of the maintenance visit

The guider should be responsible for gathering the information, registering it in files (one per FTA). He should also prepare a weekly report to put at the disposal of the maintenance team and on which the maintenance team will write down what they have done and what needs to be done. Finally, the maintenance teams should come on a regular basis (once a week for example), so that the Pumping Station team knows when they come and prepare to transmit to them the list of their tasks.

Instead of having a limited number of large teams, coming altogether with a big truck and a pick-up, it would be more efficient to have several light teams, patrolling on motorbikes, with a few tools only. These maintenance technicians would constitute numerous and mobile teams. "Heavy" teams should move only in case of a need for heavy work, like welding or basins cleaning.

The prevention

The maintenance teams should come on a regular basis and program in the year additional campaigns of prevention:
-cleaning of the strainers of all the proportional watermeters,
-checking of the actual flow at FTAs and comparing it to the value given by the removable water-meter
-checking of all pieces of the rotating screens and trash rack

The maintenance data registration and computerization per FTA gives the ability to detect easily which FTA has to be particularly watched out (because no visit since a long time or due to recurrent problems)

Further suggestions

For the maintenance of the water meters
-Choosing one water meter type
-Choosing a kind of water-meter, that allows, when there is a need to check it, to withdraw in the field only but entirely the metering part, and to replace it easily by a spare part
-having a stock of spare parts to avoid replacing the entire Water Meter
-if the watermeters contains a strainer: a flexible flange could help to remove the inside strainer, then to clean and replace it quickly, in the field.

For the maintenance of the flow limiters:
-Calibrated "ring" supplied by the manufacturer, to calibrate the hooks.

1.2.3 JVA should reform the inspection teams and establish a real double control of JVA teams work in the field.

Comprehensive computerization and registration

It would allow a systematic analysis of all the operational and maintenance issues. For the Directorates, it would be a management tool, because it will make appear where are the problems, how extended these problems are, in order to organize, for example, general campaigns of prevention or to adapt the tasks of their transversal teams...

Closer Management, Monitoring and control of JVA local staff

The local staff is lightly controlled in their everyday tasks, whatever important these tasks are. There should be by an independent entity, maybe under the responsibility of the Secretary General Assistant, responsible for:
-establishing officially, with the Directorate, the tasks and responsibilities of each worker
-requesting and analyzing activity reports, from each level
-performing surprise visits all over the turn-out stations, to check the validity of these reports, for example the water-meter readings, or the maintenance status.
This team could be equipped with pressure data logger or removable water-meter, that they could leave in the network to verify the efficiency of the operation.

1.3 Problems linked with the allocation system: the non-correspondence between water deliveries and crops requirements in sensitive periods.

1.3.1 The comparison between CRW and actual water deliveries makes appears serious irrigation deficit or excess according to seasons.

In 2003, the French Mission for Agriculture and Water has conducted a study in TO 41, to assess the real water consumption by the farmers all along the year and to compare it with the theoretical water demand by their crops. This study was based on a survey and on data supplied by the JVA (cropping pattern and allocations/consumptions) and by NCARTT[8] (meteorological data, ETo).
In Wadi Ryan, the major part of the area is cropped with vegetables in open-field; the resting part is cropped with citrus trees. On the previous years, the combination of climatic conditions and plant needs makes it appear, that the peak periods for irrigation requirements are:

- April-May for the spring vegetables
- September-October for the winter vegetables
- Summer for the citrus.

On the other hand, the JVA allocations system, as it was until 2003, divided the year in two periods:

- from the end of rainy season (April) to beginning of next rainy season (November), each kind of crop (Banana, Citrus, Vegetables) receives a fixed allocation calculated in mm/day: respectively 8, 4 and 2 mm/day. In case of drought, this allocation can be reduced by a percentage which can reach 50%.
- during the rainy season (winter), the water resource is much more abundant and the irrigation needs are reduced. So the water is distributed to farmers when they request it.

It appears through our study that:

For Citrus, the 100% allocation (4 mm/day) should be sufficient, even during the peak period, if farmers control weeds and have efficient irrigation system (80-90%). Out of the peak period, the irrigation requirements are much lower than 4 mm/day and important savings could be achieved, if the efficiency of the system allows it. But the actual efficiency is generally low (50-70%) and during the peak period (summer), water lacks seriously. This is reinforced by the illegal citrus presence, which cover large areas. As a result farmers tend to direct towards their citrus the water rights of other crops, which they consider less profitable.

For winter vegetables, irrigation requirements are close to zero between December and February, due to frequent rainfall, low temperature, high humidity in the air and weak solar radiation. At the end of October, however, due to the conjunction of advanced plant development and of the climate from September to mid-October (still dry and hot), a water deficit may appear and induces a stress. Finally, from September

[8] National Center for Agricultural Research and Transfer of Technologies

to mid-October, the JVA water allocation is also highly needed for land preparation. For example for potato plantation we estimated that 3.6 mm/day in average are needed within 2 weeks when the JVA allocation is only 2 mm/day.

For spring and summer vegetables, until the beginning of May, JVA allocation is generally sufficient. During May, plants are fully developed and the climatic demand doubles dramatically - during the most critical period for fruits.
During summer, the irrigation requirement is still much higher than JVA allocation, but farmers keep only the few vegetables adapted to high temperatures (okra, eggplant).

The synthesis of these calculations per crop at the level of the farms indicates that vegetables farms receive water in excess during the winter and the late summer, whereas they experience several crises in spring and autumn.
For farms with vegetables and citrus, they receive water in excess at end of the summer when vegetables have been harvested. On the other hand, they also experience severe crises in spring, at the beginning of summer and in autumn.

Farmers have different methods or ways to adapt to this situation of scarcity:
- Some farmers consume more than their allocated water: with FTA flow higher than the nominal and with illegal openings
- Farmers request Extra-hours to JVA stage office: this is the only flexibility that exists in the allocation system, but there is an urgent need for clarified rules and more transparency.
- Farmers adapt their cropping pattern: For example, a share of the area stays bare to transfer its water rights to the rest of the fields.
- In TO 41, some farmers have access to other resources
- Water storage: Pool capacities are around 430 m^3. Even if it is not the first function of pools, according to farmers, it can be strategic in peak periods for a complement during a short time.

As a conclusion, in TO 41, rainfalls are generally sufficient to fulfill Irrigation Requirements in winter and farmers commonly over-irrigate during this period. Over-irrigation commonly occurs during late summer, as well. The main problems for farmers are insufficient water for vegetables in April / May and for land preparation for winter potatoes.

1.3.2 A proposal: the Water banking

This study has shown that this JVA water allocation is not precisely adapted to actual crops irrigation needs, neither in quantity, nor in scheduling. JVA could optimize its allocation system, in order to improve the service delivered to farmers, but also not to waste water, neither in winter, nor in summer.
The idea came from the farmers originally when the French mission has proposed to support a water users association. Their idea was to adapt the allocation system so that farmers, when their needs are high, could receive and use the water that had been saved when their needs were low (summer for vegetables and winter for all crops).
The French Mission got interested in this idea because it has a major benefit: beyond the fact that the water supply will be more adapted to farmers' needs, more predictable

and more reliable, it would be, at last, a real incentive for farmers to save water. Indeed, until now, farmers have no interest in not using entirely the water they receive, which is obviously supporting over-irrigation[9] during some periods.

Anyhow, the main condition for establishing such a "Water Bank" is to regulate the flow of the canal all along the year. This is mainly conditioned by the existence of a sufficient storage capacity. We think that, within 2 years, the Wehda Dam could be a key for the system improvement, by allowing the JVA to master the winter flows which were not retained until now. In the future, the canal regulation along with a fine metering and with a performing WMIS[10] could allow JVA to establish an on-demand system.

But a "Water Bank" would need many efforts and further thoughts from the farmers:

- Anyhow, farmers would have to adapt to a limited global water supply per year, fixed in advance by JVA, as well as to the limited hydraulic capacity of the JVA network. They could **<u>not</u>** take **as much** water as they want, **when** they want.
- Farmers will be obliged to forecast and schedule their irrigation according to Crop Water Requirements and to monitor it carefully.
- The participation of **Farmers' Associations** could be considered to implement this system: Need for intensive communication between Water Users (farmers) and JVA and for organization between farmers, especially to adapt week after week the rotation schedule to the needs of the farmers.

On the other hand, a "Water Bank" would require many efforts and further studies from JVA. On the short term, the Water "bank" system would be difficult to implement on a large scale. **But JVA should implement pilot projects in order to prepare the future management system, to be able**:

- to operate 100% the WMIS, in order to forecast early enough the water supply to deliver to each turn out and to each farmer,
- to model all the JVA networks and to master their computer use, in order to adapt quickly the rotation schedules according to farmers' requests,
- to follow and register all the water deliveries and flows, in order to monitor the system,
- to establish a system to compensate farmers if they take less than their allocation.

Conclusion: difficulties to be considered if these changes should be extended to the other areas of the Valley.

The French Mission has experimented the implementation of this set of technical and organizational measures in pilot networks. They have proved to be efficient, because, according to JVA, the percentage of farmers receiving correctly their allocation in

[9] This over-irrigation presents the advantage to induce a good leaching of the soils, which are generally well drained. But the deep percolation is not really controlled and it becomes an economical problem in what concerns losses of fertilizer. Furthermore, when soils are clayey, over-irrigation can produce roots asphyxiation and damage the production.

[10] WMIS = Water Management Information System is a computerized data bank with all planned cropping patterns and water resources used to program the JVA water deliveries.

2003 was higher in TO 2 and TO 41, in comparison to the other networks of the Northern Directorate.

As a result, the French Mission is supporting JVA in the design of a new project which would be the extension of these measures to the whole Northern Directorate networks. But some difficulties may be considered for JVA and for the farmers:
First some farmers may resist against the comprehensive shift to 6 l/s without subsidies and technical assistance. This may concern farmers still using surface irrigation, which represent a minority today, but who are also mainly “absentees” with high “political” importance.
As far as farmers are concerned, social situations and lack of interest may also slow the farmers' organizations or farmers' participation building.

On the other hand, not only farmers could be reluctant, but also JVA staff could resist to the changes. Indeed, the new measures induce an increase of work and control, in comparison to their initial situation.
Furthermore, in certain areas, rehabilitation works may be somehow expensive, if all the water meters and FTAs have to be repaired, as well as the pumping station equipment.
Finally, the experience has shown that implementation of all these measure is difficult in itself. Indeed the proposal of the French Mission is a set of numerous different changes, and all these complex changes must be done simultaneously to be really efficient and to improve the quality of the services, which is necessary to get the farmers' support.

2 Improvement of the "on-farm network" management

The aim of the French Mission was to propose technical on-farm improvements and demonstrate in the field their feasibility and efficiency, as well as their limits.

2.1 Design on-farm

The MREA has been supporting farmers in the transition towards lower flow and higher pressure. MREA has helped interested farmers by redesigning their networks and subsidizing a share of the changes.

2.1.1 Actual changes in TO 2

Due to the decrease of the in-flow, the main on-farm issue in TO2 was to support the compulsory shift from surface to localized irrigation.
Therefore, the MREA has supported the development of microsprinklers[11] (also called "variojet"), even if many farmers initially preferred the"opentubes", a technical

[11] See our article "The Microspinklers" on www.mrea-jo.org

solution intermediate between surface and localized irrigation. Opentubes are simple pipes connected to the manifolds and flowing into a basin at the bottom of each tree.
Compared to opentube, the main interest of the microsprinkler is the lower flow, which has several interests:
-Less Head-Losses: Even with low head pressure the operation will stay satisfying, with a good uniformity inside the blocks.
-Possibility to operate a large number of emitters at once: To increase the size of the operational blocks induce savings on labor time as well as on valves and secondary pipes.
Another interest of the microsprinkler, compared to opentube is the absence of basin, which means less labor for the maintenance of the basins themselves, easier mechanical weeding.
Finally, the biggest advantage is a better uniformity of the distribution of water, reducing problems of deep percolation down the better watered part of the basins.

The variojet system seems to be accepted because it is relatively cheap and because it gets rarely plugged and can be cleaned easily. Furthermore farmers appreciate being able to see and therefore estimate the water jet.

Some difficulties appeared, like manufacturing problems (leakage of plastic…). Furthermore the suppliers generally do not give farmers the emitters characteristics (nominal flow rate, flow/pressure law, wetted area) and the farmers also do not ask for them because they do not know the hydraulic bases to design and operate their networks, which result in too low pressure and non-uniform flow. Finally, farmers do not pay enough attention to the filtration of the water.

As a result the suppliers should improve the quality of their products and their services to farmers. We see also here the accurate need for extension concerning the management of the on-farm irrigation network.

Two years later, in Adassyeh, the shift from opentubes to microsprinlers is still going on, even without the MREA financial support. This means two things: on the one hand the technique has proved its efficiency and on the other hand the pressure that is required for the microsprinklers is now available and trusted by the farmers (who work without pool).

In parallel to the pressurization of the on-farm network, the engineers of the French team have also supported farmers to improve the design of their blocks. The actual main changes have concerned the diameter of the mainlines and of the manifolds. Indeed, when farmers have installed their networks, many of them have under-dimensioned their pipes, on the one hand because they thought they were saving money, on the other hand because they were badly advised by the suppliers. And in spite of the decrease by 1/3 of the flow, many mainlines and manifolds had too limited diameters: 110 mm instead of 90 mm for the mainlines, 63 to 75 mm instead of 50 mm for the manifolds, for example.

2.1.2 Actual changes in TO 41

In TO 41, the issue was different from the situation in TO 2: all the on-farm networks were already pressurized, even in the case of citrus orchard (opentube).
The defaults of the existing networks were mainly: too narrow mainlines and manifolds, and too long laterals. According to a detailed study of each on-farm network, it appeared that, despite the shift to 6 L/s, the diameter of 25% of the mainlines should be partly increased. Actually, among the design changes that the MREA team has done upon farmers request in 2003, 64% concerned the enlarging of mainlines and manifolds and 37% the diminution of the blocks area or the length of laterals.

2.1.3 Movable pressure gauges allow on-farm management

To follow if their pressurized irrigation networks are correctly operated, farmers need to measure often and in several places the pressure of the water:

- **To Check the good working of the network**
- **To Manage irrigation blocks**: to choose with accuracy the number of blocs they can open at once to ensure an adequate pressure at emitters level.
- **To Manage filters**: to follow the evolution of headlosses between upstream and downstream the filter. For example, head losses for a clean disc filter is around 0.2 - 0.3 bars, whereas it reaches 0.5 - 0.6 bars when discs are plugged.

As a result, it is very useful for farmers to have several spots to measure pressure: FTA, pump, filter, mainline, laterals... Removable pressure gauges allow this and make the farmer save on the number of gauges as well as on their life length.

Further suggestion: Support the water-metering inside the farms
Farmers have generally only one water meter at their disposal to manage their irrigation: the FTA water meter. The large majority of them do not know how to verify the amount of water they apply to their farms, and are very far from registering it. They manage their irrigation in number of hours per block and not in mm[12], because they do not know what is the flow demand from their blocks (nominal and actual flow per emitter).

2.2 Fight against clogging

In what concerns their irrigation systems, the clogging of emitters is for farmers the most serious and common problem, especially with in-line drippers. Indeed, when emitters get clogged, the irrigation efficiency is seriously lowered: the irrigation uniformity is disturbed so that certain plants get too much water (and fertilizers) whereas others are under-irrigated and under-fertilized. As a result, the yield and output are negatively affected. If the clogging is not mastered, this means that the farmer has to renew his laterals more regularly. Therefore the clogging can be directly

[12] Knowledge of the exact irrigated area and the exact volume of water are needed to estimate the mm (1 mm = 1 m^3 per dunum)

seen as an economical problem for farmers: lack of production counting even more than the additional cost of the replacing. The farmers are highly aware of the problem, especially when they have greenhouses and high value crops: they re-new their laterals every 1 to 2 years.
The French Mission has explored in the field different techniques to prevent and decrease the clogging of emitter.

2.2.1 Better filtration

In the Jordan Valley, along with the localized irrigation farmers had generally adopted a filtration station "sand filter + screen filter", copying the first modern farms.
As a result of bad use of the sand filters, these have not satisfied farmers who have gradually abandoned them. Therefore, most of the farmers, in the northern Jordan Valley, have nowadays only screen filters. These screen filters are generally in bad status (rotten, leaking). Furthermore, the farmers do not know how to monitor the filtration based on pressure monitoring (as explained in the previous part).

In TO 2, the first step was to introduce the use of pressure gauge to monitor the filtration, and at the same time to improve the existing screen filter, by proposing optimized designs for the cartridges[13].

The second step was to introduce the disk filter, which has numerous advantages in comparison to the screen filter: bigger area of filtration, better quality of the manufacturing, efficient locking and tightening system, resistant to time because mainly out of plastic, possible backflushing when 2 filters in a row, with sufficient pressure. The transition from screen to disk filter should also be facilitated because its operation is similar to the screen one and because they are in the same range of price[14].
After two years of demonstration on-farm, farmers are now convinced of its efficiency: the demand for such devices has strongly increased, even out of the pilot areas.

In 2004, the French Mission has decided to re-introduce the sand filter, in association with disk filters, which is the most efficient system, because it retains a large quantity of particles of all sizes, due to the large area and to the thickness of the media. The cleaning of the sand-filter is easy, quick and efficient and it needs limited labor, once it is mastered by the farmer, because it is not a manual cleaning manual, as for screens and disks, but a back-flushing, which does not require interrupting the irrigation process.
What the French Mission would like to determine and to transmit to farmers is how to choose the right capacity of the filter, the right media, how to proceed to a right back-flushing, based on head-losses monitoring and how to maintain it. With a proper extension program and possibly some initial subsidies, the media-sand filter could be re-introduced, especially in the intensive farms, and solve most of the "on-farm" filtration problems.

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[13] Another attempt has been to implement a hydrocyclone in a farm from the end of a line, where the sand content of the water was making problem; but the solution would rather have been to open the ending and to flush the line!!!
[14] For more details: see our article "Plastic disk filter", on www.mrea-jo.org

2.2.2 Prevention: improve and facilitate pipes flushing and ensure nominal pressure in the blocks

When the velocity of the water is too low, the sediments still present in water after the filtration tend to settle. This happens when the irrigation stops and the water slowly withdraws, as well as when the flow in the lateral and the pressure at the level of the emitter are too low.
Before starting irrigation, farmers should monitor the status of his pipes and then flush them if necessary. But because this requires labor time at each irrigation (farmers open and close all laterals one after the other), few farmers do it properly. MREA is therefore testing a "facilitating" system: a pipe, of a bigger diameter than the laterals, is connected to the end of a set of laterals and collects their water. When the flushing is necessary, one needs to operate only one valve at the end this flushing-pipe.
Concerning the issue of the insufficient flow and pressure: Farmers try generally to irrigate as quickly as they can. Therefore, they open too many blocks at the same time. This has two consequences: On the one hand, the demand-flow is too high for the mainline and for the filtration system, which induces high headlosses. Thus the pressure at the level of the emitter is too low, in comparison to the nominal pressure: we observed that most of the time, the farmers operate their blocks at 0.3 - 0.5 bars, instead of 1 bar. As a result, the flow becomes laminar instead of turbulent, which favors settlement of the suspended solids. This low-flow has another negative effect: the lower the flow, the lower the flow uniformity in the block.
On the other hand, the entering flow is generally lower than the nominal demand flow, and gets divided into a high number of blocks, so the water velocity in each lateral is lower than it should, which favors sedimentation in its turn.
As a result, MREA encourages farmers to use movable pressure gauge (see previous paragraph) to check if the operating pressure is sufficient, and to close blocks if necessary.

2.2.3 New dripper-lines

The settling of the fine sediments does not only appear along the lateral but also IN the emitter, when the dripper is in-line. This phenomenon is obviously favored when the dripper is placed at the bottom of the pipe, in the field. The difficulty is that, in traditional GR pipes, the position of the emitter is not monitored when the dripper-line is manufactured.
Nevertheless, new kinds of pipes have entered the market, for which the emitters are aligned on one side of the pipe. The pipes in question are "tape-pipe" or "lite-pipe". Along with a completely new design of the emitters, they are characterized by a much thinner wall. As a result, they present other advantages compared to traditional GR: lower price, low nominal pressure, bigger diameter creating less headlosses, then allowing longer laterals.
In 2004, the French Mission has initiated to experiment these pipes in the framework of the clogging fight, keeping in mind that other problems may appear, like the fragility of the pipes, especially in case of very hot weather.

2.3 Tensiometric scheduling of irrigation

The climatic method (calculation of CRW based on ET_o, K_c and irrigation efficiency) is adapted to the design of an irrigation project[15] but not to on-farm irrigation management. Especially in special conditions due to the use of plastic mulches, of plastic tunnels… the adapted K_c are not available. In order to use the climatic method, one needs to be aware quickly of the ET_o ... which is particularly difficult if the farm is not equipped with its own meteorological station. Finally, the estimate of irrigation efficiency is particularly difficult.
On the other hand, tensiometers measure directly the actual availability of soil water for the plant. The method is theoretically much lighter for the farmer, because it does not need another source of information. The automation of the irrigation based upon tensiometers is even possible, for the biggest farms (bananas, grapes…).

But tensiometric scheduling of the irrigation presents many obstacles.
The first one is its high cost: 200 - 250 USD for one measurement box, 20 - 30 USD each watermark[16]. For example, for one crop, in each homogeneous area, the farmer would need from 6 watermarks (3 sites, with 2 watermarks per site). Then for 2 homogeneous areas, the total initial cost would be 250 + 12 x 25 = 550 USD. To this must be added the cost of the renewal, every 3 years. Another aspect of its cost is that it requires labor: if the system is not automated, all the watermarks must be read on a daily basis, then the farmer or its technician must build the corresponding curves, then analyze the evolution of tensions to make his decision concerning the next irrigation.
The second main obstacle concerns the method itself, because there is no immediate method to schedule irrigation. Each irrigated crop is a system combining soil-crop-climate-irrigation, for which the evolution of tensions will differ.
The way of placing the watermarks needs pre-study of the soil, of the roots position, shape and depth, and of the irrigation system. Then, there are no previously available references for "threshold tensions" (at what tension the irrigation has to be initiated or stopped). All these references have to be acquired by the farmer before initiating any kind of scheduling.

As a result, the farmers who could be interested in such investments in equipment and technical labor will be the farmers strongly motivated for saving water (high cost of pumping in the highlands, costly desalinated water…), as well as the farmers interested in fully uniform application of fertilizers and water (intensive farming in green houses, cut flowers for export…) or interested in reducing the excess of humidity (fungus development like botritys on strawberries…).
This method allows the farmer to schedule precisely and better his irrigation (for example, reducing the lack of aeration for roots in clayey soils) and generally allows water savings.
But one has to consider that such a "fine tuning" with tensiometric scheduling will only be valuable if the irrigation uniformity of the network is already high (perfect design and operation) and if all the water deliveries are precisely monitored (actual

[15] The classical climatic methods are useful, there is no need to recalculate new Jordan valley K_c or Et_o but specific conditions require specific measurements (green houses, mulch…).
[16] Hydraulic tensiometers may also be used, but are more expensive than watermarks, and are also more difficult to operate.

pressures and flows of each block and emitters, number of emitters in each block, area of each block…).
As a result, global important water savings, based on the training of farmers on tensiometric scheduling of irrigation, should not be expected. For example, in the Highlands, it is highly possible that, if farmers are able to decrease their water consumption, they will rather extend their irrigated areas than save water.

Tensiometric scheduling of irrigation is also a very interesting method to measure actual water consumption in the field. Indeed, the tensiometric monitoring of the path of water in the soil allows to control and to avoid deep percolation. In such a controlled operation, the amount of water which is delivered to the plants corresponds to their actual consumption. Tensiometers are thus a very precious tool for scientific studies and acquisition of references.

As conclusion, tensiometers are expensive tools adapted to scientific researches. Only very "technical" and motivated farmers can afford it and acquire the know-how.

GENERAL conclusion

Due to the water scarcity, at the national level, in order to increase the efficiency of the irrigation, the Jordan valley water delivery network has been modernized and shifted to pressurized systems.
This modernization took place inside the farms as well. Most farmers shifted to localized irrigation, not only to save water, but also to improve fertilization efficiency and to save labor (drip irrigation being the most adapted to plastic mulch for vegetables).
All the problems that we previously described bring the evidence that in both cases, technical advices have not been sufficient to support these important technical changes. Therefore extension services to support farmers and more technically efficient and controlled water delivery services should be developed.
But the problems are not only technical. The development of the private sector participation, including the farmers' participation, and a deep reform of the in charge institution (JVA as of today) could be proved necessary to ensure satisfactory and sustainable water resource management.
New developments, like the soon available regulation of the canal flow by the Wehdah Dam, could facilitate in a short term the water management in the Jordan valley. Anyhow, the necessary increase of water prices and the necessary development of treated waste water use will constitute important new challenges.