Water in the Arab World:

MANAGEMENT PERSPECTIVES AND INNOVATIONS

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Egypt: Irrigation Innovations in the Nile Delta

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Introduction and Statement of the Problem

Egypt depends almost entirely on 55.5 billion m^3 per year of water from the Nile River. This allocation represents 95 percent of the available resource for the country. Approximately 85 percent of the Nile water is used for irrigation. Demand for water is growing while the options for increasing supply are limited. Egypt faces the challenge of improving the productivity and sustainability of water use. To respond, the Ministry of Water Resources and Irrigation (MWRI) has been implementing an Integrated Water Resource Management (IWRM) Action Plan. Its *key strategy is to improve demand management*. This plan has had the support of the World Bank, Germany's KfW, the Netherlands Development Cooperation, and other donors.

The Integrated Irrigation Improvement and Management Project (IIIMP) is an important measure of the IWRM action plan. IIIMP is implemented on 500,000 acres (*feddans*) in the Nile Delta covering the command of 2 main canals, Mahmoudia and Mit Yazid. The project aims at improving the management of irrigation and drainage in the project area and increasing the efficiency of irrigated agriculture water use and services. The main interventions of the project are improving irrigation and drainage systems and improving the water management institutional structure.

[†] This chapter was prepared in close collaboration with the staff of Egypt's Ministry of Water Resources and Irrigation (Irrigation Improvement Sector; IIIMP Management Unit; Water Management Research Institute) and Ministry of Agriculture and Land Reclamation (Executive Authority for Land Improvement; Soil, Water and Environment Research Institute; Center of Agricultural Economic and Statistics).

The IIIMP interventions in irrigation modernization are based on the experience gained from several preceding and ongoing projects. The original concepts of irrigation modernization were developed in the early 1980's and since then have received support from UNDP, USAID, Japan, World Bank, KfW, the Netherlands Government, and others. In 1996 implementation started on the World Bank/KfW-financed Irrigation Improvement Project (IIP). It was the first large-scale application of the irrigation modernization program in Egypt. The project closed in December 2006. By that time, 50 percent of the tertiary and secondary systems of the command areas of the main canals of Mahmoudia and Mit Yazid had been modernized.

The IIP included three types of improvements/innovations:

1. *Introduction of continuous flow*. The mode of operation of secondary distribution canals was changed from rotational (for example, 5 days on/5 days off during the summer) to continuous flow (that is, water flows continuously in the secondary canals). The purpose of continuous flow was to improve water delivery services to the farmers. It has given more flexibility to the water management system to make it more suited to growing high-value crops.
2. *Providing a single lifting point*. The low-lying tertiary water systems (*mesqas*) were replaced by pressurized/elevated systems. Water is lifted from the secondary canal into the tertiary network through a single-point lifter rather than the old system. The latter allowed farmers to lift the water through several formal/informal control points without adequate control measures. The old system caused tremendous inequity in water distribution between upstream and tail-end users. The new system has led to better water distribution equity and reduced operation cost.
3. *Piping tertiary canals*. Earthen open tertiary canals were converted into piped canals. Piped canals allow for pressurized water delivery, reduce seepage losses, prevent discharge of solid waste and sewage into the tertiary system, and save approximately 2 percent of the total command area.

The IIIMP widened the approach of the previous Irrigation Improvement Project (IIP). The initial driver was based on the economic analysis of various technical irrigation improvement options, including the IIP approach. Average IIP improvement costs were exceeding LE 6,000 per feddan (extreme cases reached 12,000 LE/fed), due mainly to over-design. In addition, IIP's economic rate of return (ERR) was lower than expected at appraisal time.

In addition to reducing the cost side of the interventions, a number of innovative measures were considered to maximize the benefit side of the project from both economic and financial points of view. For example, at this time, the Egyptian government was implementing diesel fuel cost increases. These increases not only have increased the operational cost of nonimproved systems but also would have increased operational costs for improved systems if the original choice of IIP of diesel single lifters had been adopted. The proposed response was to take advantage of the relatively good electrical transmission and subtransmission infrastructure in the Nile Delta and the economic efficiency, life span, and capital and running costs of the electro-pumps.

In general, IIIMP adopted a three-point strategy:

1. Proper sizing of the improved infrastructure to optimize capital costs
2. Technical innovations to increase cost-savings and functionality
3. Extension of the improvement package to the whole system (including tertiary and on-farm improvements).

Both (2) and (3) would have resulted in maximized benefits compared to the associated costs.

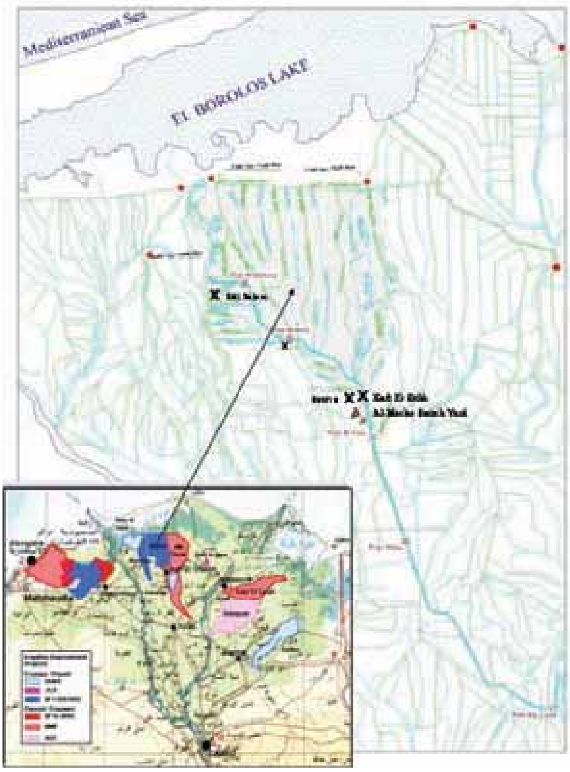
Government engineers were reluctant to endorse the elements discussed during preparation for two reasons. First, this strategy had never been implemented in Egypt. Second, there was concern regarding possible rejection by farmers of innovative elements with which they may not have had experience before. It was clear that only a "sizeable pilot" could clarify the large number of issues and fine-tune the appropriate technology before scaling up to the national level.

The objective of this chapter is to document the process of developing the pilot and to provide an interim evaluation based on real measured data. There is a real need for this evaluation at this time due to the fact that the irrigation modernization package implemented in this pilot has never been tested before under Egyptian conditions.

Selection of Pilot Area

The W-10 area in Kafr El Sheikh Governorate was selected to serve as the "sizeable pilot" for the new approach. It comprises approximately

Figure 24.1 Layout Map for Northern Part of Mit-Yazid Canal Showing W-10 Subproject Area



6,000 acres in the most downstream tail-end command area of the Mit Yazid main canal. It is supplied by 3 branch canals and 2 sub-branch canals (table 24.1). The area was selected solely because it was the only subarea in which no IIP interventions had ever been made.

As a tail-end area, W-10 has restricted water supply in the peak summer season and therefore reuses drainage water. The water shortage and low farmer incomes meant that W-10 was a more difficult working environment than the IIIMP overall.

On the positive side, the W-10 area is close to the Sakha Experimental Station.[1] This fact, together with the support of the GTZ-MALR Agriculture Water Management Project, was considered a plus, because it would enable the provision of technical assistance and materials to implement the pilot actions.

Package of Actions to Test for Scaling Up

Substantial differences existed between the old design criteria implemented under IIP and the new approach applied in W-10. The latter featured 12 innovations:

1. Electrification of single-point lifters (mesqa pump sets) rather than diesel pumps. While this measure has had the benefits mentioned above, a new dedicated distribution grid was needed, and the MWRI was to take care of it.

[1] Sakha is a subsection of the Soils, Water and Environment Research Institute (SWERI) of the Ministry of Agriculture and Land Reclamation (MALR).

2. Adoption of prepaid electrical cards to avoid delinquent payments and facilitate supply logistics to user farmers. This measure was adopted because the electric utility companies were reluctant to accept the new users based on risks of delinquent monthly payments from farmers. The IIIMP team proposed a “new deal” through the use of modern “prepaid credit cards.” This was a win-win option for both farmers and utilities.
3. New and cheaper equipment for the tertiary distribution systems (mesqas): increased irrigation application time in the peak month from 12 hr to 20 hr; substantial reduction of pipe diameters; direct pumping rather than costly concrete standpipes; more compact pump houses equipped with smaller pump modules: 20, 40, and 60 l/s, instead of 60 and 90 l/s units (reducing water duties from 4–6 l/s/ha in extreme cases to 2 l/s/ha or 0.82 l/s/acre in Egyptian customary units).
4. Improvement of head works control gates of branch canals through telemetric instrumentation and remote operation of gates with Supervisory Control and Data Acquisition (SCADA) system.
5. Improvement of quaternary distribution systems (*marwas*) including the testing of two options: lining by brick and mortar or piping by low-pressure pipes up to the on-farm gate. MWRI had not been involved before in the improvement of marwas. However, the Soil, Water and Environment Research Institute (SWERI) of the Ministry of Agriculture and Land Reclamation (MALR) was implementing a pilot program to line marwas using bricks and mortar. Thus, an interministerial agreement was made to enable SWERI to implement the marwa improvement activities, although MWRI would be responsible.
6. Testing low-pressure pipes for marwas (class 2.5 bar instead of 4 bar).
7. Testing different types of valves for the mesqa-marwa interface (ball, gate, and butterfly), different brands and specifications, optional manufacturing materials (metallic, polyvinyl chloride or PVC), PE, and different installation lay-outs.
8. Developing and testing different individual farm-gate hydrants for on-farm use allowing future use of hoses and gated pipes—all provided with pre-set constant flow and pressure.
9. Application of laser land-leveling (LLL) practices to improve allocation efficiencies (recently initiated).

10. Introduction of rotational operation schedules of pumps, valves, and hydrants to harmonize farmer needs and efficient use of water, labor, and energy.
11. Introduction of on-farm water management improvements including irrigation scheduling (to begin soon).
12. Testing and introduction of modified/controlled drainage (tested at station level and to be expanded soon).

By 2009 the approach tested in the W-10 pilot area was being expanded within IIIMP to more than 500,000 acres in the Delta.

This expansion depended on the collaboration among the specialized agencies of the MWRI and MALR, working together with water user associations (WUAs) and informal farmer groups. The cooperation between MWRI and MALR in the W-10 area provided the framework for MALR participation in the implementation of marwa and on-farm improvement programs. These programs included piped marwas, laser land-leveling, and training and capacity building of beneficiary farmers.

The completion of the W-10 took more than four years due to contractors' inexperience in implementing some of the new interventions and failures of some contractors to comply with the contractual schedule. The marwa implementation schedule was delayed because of delays in agreement on procedures for interagency transfer of funds and materials and other accountability mechanisms. After the project management unit (PMU) took over responsibility for completing the W-10 area project, the marwa improvement program began to accelerate.

As noted above, the new W-10 approach was strongly resisted during the first few years. However, after the results of the W-10 pilot became evident, many of the skeptical parties became convinced that the project's technical and organizational innovations could succeed.

Evaluation of the New Approach

The IIIMP Project Appraisal Document (PAD) envisaged (a) an average increase in farmers' annual income of approximately 15 percent, (b) water savings of approximately 22 percent, and (c) an overall ERR of 20.5 percent.

An interim evaluation of W-10 pilot was conducted in late 2008. The aims were to:

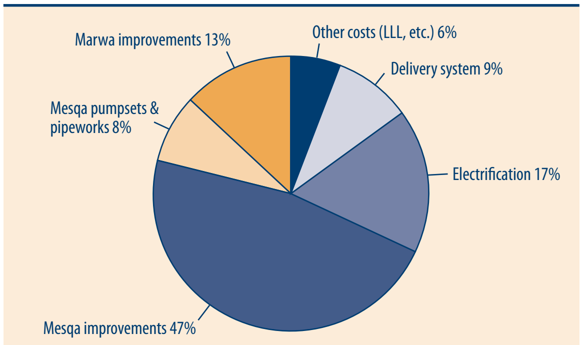
- Verify whether the new approach was feasible and whether the PAD forecasts were accurate
- Inform the design of a results-oriented monitoring and evaluation system.

Investment Costs

Most of the W-10 improvement costs were financed by IIP, which closed on December 31, 2006. The improvements at the quaternary and on-farm levels were taken on by the IIIMP. Despite having an estimated cost of approximately LE 120 per acre—less than 2 percent of the total improvement costs—laser land leveling is expected to have a significant impact.

Figure 24.2 shows the breakdown of the main components of the improvement costs in the W-10 pilot. Mesqa improvements represent 47 percent of all W-10 improvement costs.

Figure 24.2 Breakdown of W-10 Investment



Source: Authors based on data from official records.

Improvement in Physical Performance of Irrigation System of the W-10 area

At the time of writing of this report, the authors could not assess the full range of enhancements in irrigation system performance because the improvement package had not yet been implemented in full (for example, the crucial laser land-leveling improvement). However, through a number of ongoing M&E studies, the following preliminary observations have been evident:

Impact of marwa improvement

- The *sufficiency indicator*, which expresses whether enough water is diverted by the marwa to its served area, is the highest for pipeline marwas compared to lined and earthen marwas (earthen is the lowest).
- The *equity indicator*, which measures adequacy of water distribution, is the highest for pipeline marwas, compared to lined and earthen.

- The *conveyance efficiency indicator* depends on calculating water losses due to seepage, percolation, and evaporation from marwas between the source and the farm. This indicator was highest for piped marwas. Piped marwas resulted in substantial water saving compared to other interventions.
- The *irrigation time indicator* indicates the superiority of improved marwas over earthen marvas.
- *On-farm* (application, crop water use, and field water use) *irrigation efficiency* is highest for piped marwas.
- *Water table depths* were deeper for improved marwas compared to earthen ones, indicating less water loss and lower drainage coefficients.
- The s*ocial assessment* indicated that most farmers prefer piped marwas. The farmers perceived four benefits from improving marwas: equity enhancement, land-saving, reduction in maintenance costs, and reduction in irrigation time.

Impact of mesqa improvement

- The average total operating cost was significantly lower for W-10 compared to the IIP regular improvement package.
- The average irrigation time was higher for W-10 compared to the regular IIP-1 due to reduced pump size and pipe diameters in W-10 area.
- Relative water supply is better for the W-10 area compared to the nonimproved areas, thus indicating better water availability.

Benefits in W-10 Pilot Area

Appendix 24.1 shows which irrigation improvements produced which benefits.

Benefits could be summarized for one or several of the improvements by the following actual production parameters:

- *Crop yield increases* (due to enhanced flexibility under continuous flow operation, timely irrigation, equity for tail-end farms, improved water quality and quantity, improved drainage and reduced water table and water and soil salinity, and reduction of weed infestations)
- *Change in cropping pattern* (due to improved reliability and timely access to water)

Table 24.1 Average Incremental Yields and Incomes by Crop

	Crop yields *(kg/fed)*			Income *(LE/fed)*		
Crop/activity	Without project	With project	Increase *(%)*	Without project	With project	Increase *(%)*
Maize	3.100	3.500	13	3,355	4,042	20
Rice	4.100	4.600	12	3,140	3,928	25
Seed cotton	1.130	1.330	18	1,769	2,602	47
Summer vegetable	15.000	18.000	20	3,450	5,254	52
Wheat	2.800	3.200	14	4,871	5,868	20
Broad beans	1.400	1.600	14	2,131	2,666	25
Winter vegetable	19.000	22.000	16	6,805	8,729	28
Berseem long season	25.000	28.000	12	2,504	3,085	23
Berseem short season	12.000	15.000	25	1,067	1,748	64
Sugar beet	18.000	21.000	17	2,332	3,186	37
Citrus	10,000	12,000	20	8,995	11,528	28

- *Land gains* for communal service space (due to replacement of open mesqas and marwas by buried pipes)
- *Reduced irrigation costs*
- *Increased water productivity* (due to reduced water losses, conveyance efficiency, controlled drainage, laser land-leveling, higher yields, lower irrigation costs).

The improved production parameters recorded above all are measurable and easy to introduce into crop and farm representative budget models.

To estimate the benefits of the W-10 pilot package, the authors worked closely with officers of MALR's Center of Agricultural Economics and Statistics[2] to update with- and without-project crop patterns and budgets. Such figures were obtained primarily by field-sampling yields and some estimates based on qualified experts. Table 24.1 summarizes the resulting yields and net income parameters of the main crops cultivated in W-10.

As can be seen from the physical quantities and values detailed in table 24.1, yields are increased by 12 percent–25 percent. Net incomes per cultivated acre are increasing by 20 percent–64 percent as a result

[2] Engineers Bayoumi Abd El Megued Bayoumi, Abd Elmahab, and Mohamed A. El-din Mustafa (MALR).

of the combined effects of increased productivity and reduction of the irrigation costs (depreciation and O&M of pumps).

Table 24.2 summarizes three typical *farm models*. All models confirm the financial feasibility of the proposed improvements and the positive impact on beneficiaries' family income. Through integrated on-farm and off-farm investments, the project not only saves approximately 20 percent–30 percent of water but also significantly increases household income by 8 percent–14.5 percent (table 24.2). As W-10 pilot area investments are completed with laser land-leveling and other on-farm improvements (training, irrigation scheduling), additional income gains will materialize.

Financial and economic prices have been estimated using 2007–08 data. Conversion factors (CFs) for shadow pricing are based on estimates prepared for this quick illustrative analysis. Conversion factors for wheat (1.1), cotton (0.95), sugar beet and maize (0.9), and citrus fruits and tomato (0.8) were used. Given the high levels of existing subsidies to Egypt's energy market prices, CFs of 4.0 and 2.5 were used for diesel and electricity, respectively. For nontraded commodities, such as berseem and other forages, financial prices are assumed to be in line with economic prices. According to the most recent forecasts of commodity prices prepared by the World Bank (November 2008), future economic prices for traded inputs and outputs are not expected to show major variations. The WB forecast made no adjustment for labor costs.

Due to the short time available for preparing the analysis, no economic value was estimated for water saved. The farm model estimated that water consumption in W-10 was reduced by 30 percent from 49.6 million to 34.8 million m^3 as a result of the new improvement package being tested. However, water is gaining an increasing opportunity cost as irrigated area continues to expand in Egypt and water becomes more and more scarce.

Table 24.2 Farm Models: Estimated Income Increases *(LE/farm)*

	Income increases *(%)*	Model *(feddan)*	W-10 Area per model *(feddan)*	No. of farms	Farmer's net income	
					Without project	With project
W-10 pilot area			6,000	5,583		
Model 0.75 feddan *(50% of area)*	8.0	0.75	3,000	4,000	18,658	20,151
Model 1.5 feddan *(33% of area)*	11.9	1.50	2,000	1,333	23,222	25,988
Model 4 feddan *(17% of area)*	14.5	4.00	1,000	250	38,198	43,754

The ERR for W-10 investments was estimated at 15.2 percent and the net present value (NPV) at LE 11 million at 12 percent discount rate. These numbers were achieved even without assigning any value to the water being saved or to the significant reduction of carbon emissions from substituting the more than 5,500 individual diesel pumps with approximately 100 single-point electric pump houses.

Conclusions and Recommendations

This analysis uses empirical data to confirm that the W-10 pilot improvements are economically viable. It produced this positive result despite the fact that the project was in its start-up phase; there were cost overruns as staff became familiar with the new approach, and not all project benefits had yet materialized.

The exercise is a valid first approximation of an evaluation procedure that should be followed routinely. It should be updated regularly on the basis of systematic data collection.

Other additional preliminary conclusions that could be drawn from the analysis are:

1. As crop yields improve, the new designs introducing continuous flow and significantly reducing the capacity of single-point mesqa irrigation pumps are proving to be adequate for crop and farm needs. These designs are showing the way to improve equity in the irrigation distribution systems, which, by design, have a limited water conveyance and delivery capacity. With the new improvements approach, tail-end farmers should be in a better position to obtain the water they need. Farmers located in the head will neither need, nor be able to capture, water in excess of their crop consumption needs.
2. Electrification of the system also enables significant reductions of the costs of irrigation. The reductions result from both the reduced depreciation and maintenance costs of electric pumps as opposed to the diesel pumps, and the lower cost of electricity as compared with diesel fuel. Electrification also substantially reduces a significant source of carbon emissions from the thousands of individual diesel pumps being substituted by more efficient and environmentally friendly shared electric pump houses.
3. There is still a great possibility to reduce costs of irrigation improvement works, as implementation partners (Irrigation Improvement

Sector of MWRI; Executive Agency for Land Improvement of MALR) and private contractors learn about the innovative approaches. As investment costs are reduced with experience, the impact of the improvements will increase.

4. Integrated irrigation improvements up to the marwa and the on-farm levels are possible due to the institutional collaboration and strong support from MWRI and MALR that were developed during IIMP. These arrangements should be reinforced, and more training provided.
5. With the new approach, it is possible both to save approximately 20 percent–30 percent of the water used for irrigation and to achieve a significant increase in the value of production.
6. The evaluation exercise showed that the productivity of water increases by more than 80 percent when comparing the total net economic value of production per 1000 m^3 used for irrigation at project maturity with the pre-project productivity.

Appendix A1 Monitoring and Evaluation Framework: Integrated Improvements Components and Expected Impacts

Table A1.1 Monitoring and Evaluation Framework: Integrated Improvements Components and Expected Impacts

Infrastructure networks levels			Relevant users organizations	Improvement subcomponents (inputs)	Impact results expected (outputs)	
					Intermediate outcomes	Final outcomes
On-farm			Water User Associations (WUAs)	Laser land-leveling	Efficient on-farm water management	■ Labor savings for farmers ■ Incremental crop yields ■ Incremental energy and water savings at farm level ■ Fertilizer savings ■ Land market-value appreciation
				Calibrated farm hydrants and irrigation scheduling training	Increased crop yields	
				Salinity control agronomic packages		
Off-farm improvements and actions	Minor networks	Quaternary marwas		Marwas improvement (piping/lining)	Efficient, timely, and equitable water distribution to farms	■ Assurance of water adequacy, equity, and timeliness to farms ■ Pump energy savings ■ Increased yields ■ Water and energy savings ■ Incremental increase of land value ■ Labor savings
				Hydrants harmonized rotational scheduling		
				Controlled drainage pits	Water and pumping savings on rice crops	
				WUAs training on O&M	Effective and sustainable O&M	
		Tertiary mesqas		WUA establishment and effectiveness	Enabling condition to all actions/ improvements	■ Sustainable use of water distribution water adequacy, timeliness, and equity of distribution to marwas ■ O&M cost recovery to mesqas ■ Water and energy savings ■ Increase of land value ■ Emissions reduction
				Piped mesqa + single lifter	Enabling condition for equity and saving	
				Electrification	Reduction on pumping costs, emissions, and noise	
				Training on pumps and valves O&M and rotational scheduling	Sustainable use	
				Adoption of continuous flow at peak times	Equity and water savings	

Continued on next page

Table A1.1 Monitoring and Evaluation Framework: Integrated Improvements Components and Expected Impacts *(continued)*

Infrastructure networks levels			Relevant users organizations	Improvement subcomponents (inputs)	Impact results expected (outputs)	
					Intermediate outcomes	Final outcomes
Off-farm improvements and actions	Major networks	Secondary branch canals and surface drains	Branch-canal water user associations (BCWUAs)	Improvement of BC and related structures	Enabling conditions for mesqa improvements	■ Water adequacy, timeliness, and equity of distribution to mesqas
				BC headworks improvement and volumetric metering	Enabling condition for continuous flow	
				Renewing subsurface drains	Enabling conditions for controlling salinity and water logging	■ Sustainable crop productivity and yields: water savings on rice crops
				Modified/controlled drainage	Rice water savings	
		Surface drains (main)	District Water Boards (DWBs)	Main surface drains and related structures rehabilitation	Enabling conditions for controlling salinity and water logging	■ Sustainable crop productivity and yields
		Main canals		Main canal and related structures rehabilitation	Enabling condition for continuous flow for tail-end BCs	■ Overall equity, adequacy, and timeliness of water distribution to BCs
		Pump stations		Major pumping stations and related structures overhauling		