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SUMMARY - Egypt's irrigation system was identified, Egypt Water Use Project (EWUP) was selected as a case study. The Project conducted an applied research and extension program in three pilot areas. The general objective of the project was to improve social and economic conditions of Egyptian small farmers through development and use of improved irrigation water management and associated practices which increase agricultural production, promote efficient water use and decrease drainage problems.

Key words: Irrigation system, management, efficiency, scheduling.

RESUME - Le système égyptien d'irrigation a été identifié. Le projet égyptien d'utilisation de l'eau a été choisi comme un cas d'étude. Le projet comporte une recherche appliquée ainsi qu'un programme de vulgarisation concernant trois surfaces indicatrices. L'objectif général du projet est d'améliorer les conditions de vie économiques et sociales des petits fermiers égyptiens en améliorant la gestion de l'eau d'irrigation, associée à des pratiques qui augmentent le rendement agricole. Ces points auront aussi pour but d'augmenter l'efficacité de l'eau utilisée et diminuer les problèmes de drainage.

***Mots-clés**: Système d'irrigation, exploitation, suffisance, tabulation.*

Introduction

Rainfall is scarce in Egypt. Even the small amount which normally occurs over the Delta comes during the winter when crop demands are low. Consequently, the nation's farmlands are and have been since time immemorial, almost entirely dependent on irrigation from the River Nile.

The last century witnessed a radical change in Egyptian irrigations methods. The ancient system of basin irrigation and cultivation of one crop per year, which prevailed since the dawn of civilization, has been superseded by perennial irrigation. Due to the construction of many control structures, including the High Aswan Dam, water is now available for year round crop cultivation.

Management of the delivery and drainage systems has become more difficult under conditions of year-round irrigation and changes in crop patterns. The challenge is to minimize or solve these problems while fully exploiting the new opportunities for the benefit of the nation.

In recognition of these new opportunities and problems, the Egypt Water Use and Management Project (EWUP) was created in 1977 through action by the Ministry of Irrigation (MOI), the Ministry of Agriculture (MOA) and the United States Agency for International Development (USAID).

Egypt's irrigation system

The High Aswan Dam presently ensures Egypt's annual quota of 55.5 milliard cubic meters of water for irrigation and other purposes. The discharge of water from the High Aswan Dam is under full control. The release of water for irrigation is adjusted throughout the year to provide all agricultural areas with sufficient water for crop needs. Distributary canal cross sections are designed serve command areas according to specified water duties. Masques (private canals) are served from distributary canals which are on a two or three-turn rotation. The time interval between periods when water is turned off and when it is later turned on depends on the cropping patterns and seasonal climatic conditions.

The on-days of a canal rotation are considered 24 hour periods (starting at sundown) without any adjustments between daytime and nighttime use. The number of on-days in a turn is sometimes modified to meet farmers requests for more irrigation water.

The water supply for any given area is monitored by observing water surface levels in delivery canals. The water is typically delivered from 50 to 75 cm below the ground surface of the fields, so irrigators must lift the water into the land. Delivery canals are closed for approximately one month during the winter to permit maintenance and construction of structures. In general, the winter closure is preceded followed by a general irrigation for 10 days.

Farmers are not required to pay for water. Its use along the masque is determined by custom, which usually favours the farmers at the head of the masque. Similarly, masques at the head of a distributary canal have an advantage over those at the tail end.

After lifting water from the masque, a farmer is free to distribute it over his fields by his own method. Generally, he distributes the water through a marwa (field ditch) to small banded units called basins. The surface of the fields may be furrowed for row crops or smoothed for basin crops. Excess surface water may be drained-off into open field drains or, in some cases, back into the masque.

The best environment for crop production is achieved when the plants root zones are kept adequately moist. Either inadequate or excess water in the root zone causes plant stress and reduces yields. Good irrigation management should maintain optimum root zone moisture conditions without using excessive water. Poor irrigation management wastes water, sometimes wastes plant nutrients, contributes to potentially harmful high water table conditions, and tends to overload drains. It may also waste labour and energy required for lifting excess water to the field and from the drains.

Good on-farm water management requires level fields, appropriately designed on-farm distribution systems, and knowledge of when to irrigate and how much water to apply. It also requires a dependable source of water, available when needed, in a quantity which can be distributed efficiently over the farmers field. Consequently, there must be close communication and interaction among all farmers served by a masque and with the district irrigation engineer who regulates engineer who regulates the water upstream from the masque intakes.

The potential for achieving benefits from better water management is substantial. Approximately half the water resources available are presently required for evapotranspiration by crops. Of the remainder, most is lost from the system in the delivery process through seepage, evaporation, and flow-through. Some, of course, must be allocated for domestic, industrial and navigation uses. Any measure which conserves water and reduces losses provides an opportunity for increased agricultural production through horizontal expansion as well as reducing drainage costs.

EWUP goals and purposes

The general objective of the project was to improve the social and economic conditions of Egyptian small farmers through development and use of improved irrigation water management and associated practices which increase agricultural production, promote efficient water use and decrease drainage problems. The project was also designed to increase the institutional capacity of the MOI and MOA to develop and implement improved on-farm water management programs. These programs were to be tested and proven for technical applicability, farmer acceptability, and organizational replicability. If they met these criteria, they would be expanded to the regional and/or national levels (EWUP, 1984).

The project would conduct an applied research and extension program with small farmers in three representative pilot areas. The project was expected to:

i. Identify the major constraints to improved on-farm water management and optimal water delivery system operations.

ii. Determine and establish the use of optimal irrigation practices at the farm level in representative pilot areas.

iii. Establish improved water control practices for the farm water delivery systems and farm drainage systems in project areas.

iv. Develop plans for organization and implementation of expanded future programs based on results obtained from project areas.

v. Develop and/or train qualified professionals and technicians for the conduct of project activities.

National goals

EWUP has provided experience and a knowledge base which have been used to formulate plans for expanded irrigation improvement programs in Egypt. These programs reflect national goals. As a part of Egypt most recent Five-Years Plan the MOI intends to implement a National Irrigation Improvement Program which includes the following goals:

i. Improve management of irrigation water.

ii. Minimize seepage losses from delivery canals.

iii. Reduce water table levels.

iv. Reduce the pressure on drainage networks.

v. Control water through the distribution system from the barrages to the masque outlets.

vi. Improve water availability at the tail ends of canals and masques.

vii. Improve and renovate irrigation networks.

viii. Increase crop production.

Most of these objectives have been addressed by EWUP.

EWUP's approach

EWUP has nearly six years of experience at three field sites developing methods of watercourse improvement and packages of practices for better on-farm water use. The project demonstrated the value of an interdisciplinary approach which included engineers, agronomists, sociologists and economists who worked together to increase crop production and promote efficient water use.

The project research plan called for: (1) problem identification, (2) search for solutions, (3) testing solutions through pilot programs, and (4) developing procedures for disseminating practices which were proven through the pilot programs. Watercourse management programs were launched at each of the three project sites which involve a proven interdisciplinary model of water delivery system and on-farm irrigation management improvement. Farmers were involved and helped the professional staff identify irrigation problems, consider alternative solutions and field test those promising solutions. In applied research, these steps are necessary before developing large-scale plans for implementation at regional or national levels.

Field sites

The project's work plan called for establishing field offices and water delivery command areas at three locations in Egypt. Selections were made in Giza, Kafr El-Sheikh and El-Minya Governorate.

El-Mansuriya site is located along El-Mansuriya canal in Giza Governorate. The land within the field site is served by Beni Magdule and El-Hammami distributary canals. This site was selected because it represented the Mgdul command area is predominately alluvial clay while that of El-Hammami area is sandy. Each area covers approximately 800 *feddans*. The work emphasized at this site included channel lining, elevated masques, buried pipeline and continuous-flow water delivery.

Abu Raya site is located along the third reach of Daqalt distributary canal near Abu Raya village, 35 km northeast of the city of Kafr El-Sheikh. The field site was selected to represent the major rice producing regions. The work concentrated on command areas served by Hamad, Om Sen and Manshiya masques which consisted of 219, 235, and 246 *feddans*, respectively. Land levelling, appropriately designed level furrow and basin irrigation systems and farmers-organized masque cleaning were emphasized at this site. In 1983, work at this field site was expanded to include water delivery system improvement for the entire area, approximately 6,300 *feddans*, served by all three reaches of Daqalt canal.

Abyuha site consisted of approximately 1,200 *feddans* served by the Abyuha distributary canal, 20 km south of the city of El-Minya. The site was selected to represent upstream areas of Egypt which produce broad beans, cotton, sugarcane and other crops in the Nile River Valley. Work emphasized at this site included land levelling, long level furrow and basin irrigation, and renovation of the distributary canal and masques for improvement of the gravity irrigation system.

Cropping system

Egyptian cropping systems produce two crops per year. The MOA & LR provides supervision on the cropping system by specifying the land area for cotton and rice. The irrigation system is designed to provide water to meet the needs of the cropping system.

The general cropping patterns for the three EWUP study areas are:

ABYUHA: This is a berseem-cotton-wheat-maize area, however, broad beans are harvested in early April forcing the cotton to be planted up to one month late. At Abyuha, there is also substantial area planted to sugarcane. Soybean have recently become a major crop, replacing cotton.

ABU RAYA: The basic cropping pattern is berseem-cotton-wheat-rice. Sometimes, more rice lands than allocated are planted along the masques. This rice planting increases pressure on the irrigation system, particularly during the puddling period. Sugar beets are becoming an important winter crop replacing wheat.

EL-MANSURIYA: This area has an open cropping system of its proximity to Cairo. It is an important vegetable-growing region, but berseem occupies the largest land area in winter and maize in summer.

Following these crops, vegetables account for the most land area. Vegetables are frequently grown in some very intensive multiple crop combinations that could occupy the land for an entire year. For example, at El-Hammami, hot peppers are relay-cropped to green beans and then groundnut, prior to the final pick of the hot peppers. The groundnut hen continue until the planting date of the hot peppers. Such complex land use makes irrigation planning difficult.

In addition to the regular cropping patterns, small areas are planted to vegetables for home consumption and local markets.

Soils

Soils at the project sites are alluvial clay soils (order entisols and vertisols according to soil taxonomy), with the exception of the sandy soils at El-Hammami. Chemical, physical and salinity, and sodicity were the main constraints to plant growth and crop production. Special irrigation problems were created by the characteristically low infiltration rates of the clay soils and their physical instability. This instability was caused by shrinking and swelling during wetting and drying cycles.

Profiles of clay soils at project sites were and almost homogenous to a 150 cm depth of sampling (Dotzenko *et al.*, 1979; Selim *et al.*, 1983 a; Selim *et al.*, 1983 b). The combination of the soil type and water table conditions restricted the root zone and the measured soil water changes to the upper 30 to 40 cm of the soil profile. This resulted in an available soil moisture content of only 5 to 7 cm.

The infiltration rate of the clay soils could average a hundredfold decrease during a single irrigation, from 720 mm/hr during the first minute to 7.2 mm/hr after 2 hours (Litwiller *et al.*). This allowed fairly uniform water application, even under the wide range field sizes and variable flow rates which occur in irrigating Egyptian farmlands. Often the final infiltration rate was nearly zero, resulting in ponds that remained in field depressions for detrimentally long periods of time that remained in field depressions for detrimentally long periods of time even after fields had been precision levelled. Surface drainage was then required, in the judgement of farmers, to prevent crop damage. This problem was more severe in winter when evaporation rates were low. In Summer, higher evaporation rates helped dry ponds before they damaged crops.

Another problem with working in the alluvial clay soils was that the cracking and heaving caused by the clay expansion could make maintaining compaction on elevated canal banks difficult and could lead to seepage losses. This soil cracking was one of the primary causes of marwa conveyance losses at Abu-Raya (Ley *et al.*).

Soil fertility studied conducted at project sites showed the need for evaluation of soil nutrient status (Zanati *et al.*, 1982). Data indicated there was a wide range between the very low to very high fertility index of the different nutrients depending on the soil and the preceding crop. The most common element deficiencies were zinc and phosphorus.

Interventions tested for improving on-farm water management

Interventions tested by EWUP to improve on-farm water management included precision land levelling irrigation system design and management irrigation scheduling, and crop management.

Precision land levelling (PLL)

The level basin method of irrigation is used by farmers throughout Egypt. Achieving high water application efficiency with this type of irrigation requires precisely levelled fields. Precision land levelling activities were conducted at each of the project sites.

On-farm irrigation systems

Project activities centred on redesign of the conventional basin irrigation system. In some cases, this resulted in longer and narrower basin configuration, length of run from field head to tail ranged from 50 to 150 m. Precision level land was necessary for successful irrigation of long runs (Ley *et al.*).

Field layouts

Furrow or border length was determined by field dimensions and farmer preference in most cases. Appropriate border width depended on available flow rate at the head of the border, the border length, design application depth, infiltration characteristics and surface roughness. Necessary border dike height was determined by the expected maximum flow depth provided by the Scs[1] border design method, plus freeboard (Ley, 1983). At Abu Raya, typical border strip widths ranges from 10 to 30 meters and a typical border dike height was 0.20 m. Furrow needed to be large and well-shaped. At Abu Raya, a furrow spacing of 1.1 meters was successfully used (Ley, 1983). Field layouts were designed to minimize length of saqia-to-field conveyance channels (El-Kady *et al.*,1979). Conveyance channels were reshaped and in some cases lined, in order to reduce or eliminate conveyance losses from saqia to field.

Management

For good performance, newly designed system with long runs had to be well maintained. Furrows needed to be cleaned by cultivator prior to irrigation to maintain shape, fill cracks and minimize roughness.

Dikes which separated borders and surrounded fields needed repairing before each irrigation to control water advance along the border strip and to prevent undesirable surface drainage (Ley *et al.*). Dike maintenance was particularly important during rice cultivation because water was continually pounded on the soil surface (Ley and Tinsley, 1983).

During irrigation of basin crops, the entire flow available at the field was diverted to one border strip. For furrow crops, the number of furrows irrigated at one time was determined at each irrigation depending on the available flow rate. Typical values for furrow flow rate at Abu Raya varied from 2 to 4 l/sec per 100 m^2 of land area (Ley *et al.*). Inflow into borders or furrows needed to be stopped when the advancing water front reached the end of the field. This allowed good distribution of water across the field because of low terminal infiltration rates (Litwiller *et al.*).

Irrigation scheduling

Irrigation scheduling addresses two questions: "When to irrigate?" and "How much water to apply?" Project experience involved developing irrigation schedules based on prevailing farmers practices, measured soil water depletion, and consumptive use estimates. Constraints to implementing an irrigation scheduling program were also assessed.

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1 Soil Conservation Service

Proposed schedules

Proposed irrigation schedules were designed to help farmers follow recommended irrigation intervals based on desired soil water depletion values. Application depths were determined by the soil water deficit, and expected application efficiency. Applying less water than the soil water deficit was considered impossible with prevailing surface irrigation application methods and soil infiltration characteristics (Litwiller *et al.*). The heaviest irrigation applied a project sites occurred at crop planting due to the large irrigation gap between crops. A typical soil water deficit value for initial irrigation was about 12 cm. For Abyuha, Beni Magdul and El-Hammami areas, leaching of salts which occurred during the first irrigation was considered sufficient for the entire season. At Abu Raya, where saline groundwater presented a hazard to crop production, the flooding of rice paddies effectively controlled soil salinity. A 40% reduction in soil salinity in the 0-90 cm. Soil depth range was measured during each of two seasons of rice cultivation (Ley, 1983).

EWUP studies showed that irrigation should take place at a soil water depletion of 40 to 50% of the available water in the effective root depth. This was equivalent to a soil water deficit of about 7 cm, which was accepted as a guideline for when to irrigate. It was observed that many farmers at the project sites irrigated at this deficit for irrigations following the planting irrigation. Water application depth for irrigations following the planting irrigation had to be sufficient to satisfy the 7 cm deficit plus expected losses.

Crop management

Project work at the various field sites demonstrated improvement in crop management was required to gain maximum benefit from irrigation system interventions. Yields could be increased by implementing solutions to the prevailing crop management problems. Improved agronomic practices included timely sowing of improved crop varieties, adequate plant populations, plant protection against insects and disease, and proper rate and timing of fertilizer application. These practices, combined with water management, increased crop production. In general, it was observed that higher yields and greater returns from applied water resulted when farmers followed recommended crop and water management practices (Abdel-Naim; McConnen *et al.*).

Benefits

Project interventions in on-farm management resulted in a number of measured and observed benefits. Irrigation of long furrows and basins provided potential for mechanization of field operations (Ley *et al.*). Labour requirements for construction and operation of on-farm irrigation systems were reduced on some farms.

Because PLL minimized field elevation, farmers were able to achieve good field coverage with smaller application depths. Drainage of excess water was consequently reduced. In Abyuha, land levelling intervention resulted in application efficiencies of 70% and 75% for two long basins of 6.3 m x 133 m x 50 m, respectively, while application efficiency on six unlevelled farms averaged 61% (Ley *et al.*) 1/2. PLL was only one of a number of factors which influenced application efficiency. Other factors included flow rate, duration of water application, dike and furrow maintenance, and basin size. Similar results were also observed in El-Mansuriya area (Ley *et al.*).

In Abyuha, land levelling provided soil for maintaining, aligning, elevating and reconstructing channels. In Abu Raya, construction of long furrows and basins made possible by PLL reduced saqia-to-field conveyance channel length and saved water (Ley, 1984).

Water and irrigation time savings were realized through implementation of a package of practices in Abu Raya including PLL, irrigation system design, and management (Ley *et al.*). Table 1 is a summary of data from fifty fields during six seasons of project work. As a general trend, land levelling and conveyance channel improvements led to higher on-farm irrigation efficiencies. Higher efficiencies represent decreased irrigation time and reduced water lifting costs.

Table 1. Summary of on-farm efficiency results for six seasons of EWUP work (EWUP, 1984).

Season	Crop	Location	PLL	Conditions/Practices		$1/E_{cf}$	$1/E_a$	$1/E_{if}$
				Conveyance Basins	Channels			
Winter 78-79	Wheat	Field 3-02 Hamad Canal	No	Unimproved	Conventional	60 2/	35	21
Winter 78-79	Flax	Field 3-02 Hamad Canal	No	Unimproved	Conventional	60 2/	40	24
Winter 79-80	Wheat	5 fields on Manshiya Canal	No	Unimproved	Conventional	60 2/	63	38
Winter 79-80	Wheat	5 fields on Manshiya Canal	Yes	Unimproved	Redesigned	60 2/	99	61
Summer 80	Cotton	6 fields on Omsen and Manshiya Canal	No	Unimproved	Conventional	60 2/	87	60
Summer 80	Cotton	6 fields on Omsen and Manshiya Canals	Yes	Unimproved	Redesigned	60 2/	88	53
Winter 80-81	Wheat	5 fields on Hamad and Manshiya Canals	Yes	Reshaped	Redesigned	74	69	51
Summer 81	Cotton	6 fields on Hamad and Manshiya Canals	Yes	Reshaped	Redesigned	84	67	66
Winter 81-82	Wheat	Field 3-10 Manshiya Canal	Yes	Unimproved	Redesigned	62	85	53
Winter 81-82	Wheat and Barley	4 fields on Hamad and Manshiya Canals	Yes	Lined	Redesigned	99	76	75
Winter 81-82	Sugar Beet	4 fields on Hamad and Manshiya Canals	Yes	Lined	Redesigned	98	87	85

$1/E_{cf}$ = on-farm conveyance (see Glossary for definition)
E_a = application efficiency (see Glossary for definition)
2/Based on inflow-outflow tests

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