Modernization of surface irrigation systems in a Water - Food - Energy Nexus perspective: modelling approach

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Surface irrigation challenges and opportunities

- 86% surface irrigation
- 11% sprinkler irrigation
- 3% localized irrigation

- 3.55 M ha Agricultural land
- 2.7 M ha Surface irrigation (77%)
Water resources management in Egypt: challenges and obstacles

The Nile river is almost the exclusive source of water in Egypt (97% of the available water).

More than 80% of the available water is consumed by the agricultural sector.

- Single resource
- Increasing population
- Upstream development
- Ambitious plans
Irrigation delivery system in Egypt: The Canal System

- **High Aswan Dam**
- **River Nile**
- **Main Canal**
- **Secondary Canal**
- **Tertiary Canal "mesqa"**
- **Ditches (Marwas)**
- **Sub-branch Canals**
- **Farms**
- **On farm irrigation system**
- **Managed individually**

**Primary & secondary level**
Managed by governmental organizations

**Tertiary level**
Managed by water users (WUAs)

8.4 ha
21 - 84 ha

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IMPROVEMENT PROJECTS- A CONTINUUM

The Integrated Irrigation Improvement and Management Project (IIIMP) started in 2007.

The main goal of this program is to improve on-farm irrigation systems in 2.1 million ha in the Nile Delta and Valley during the action plan period (2011-2021) to save water for reclaiming the targeted areas in the 2030 strategic plan.

The first phase included the command areas of two main canals, Mahmoudia and Meet Yazid, with gross areas of 120,000 and 111,000 ha covering about 10% of the irrigated areas in the Nile Delta.
After modernization (current situation)

- Single lifting point
- Low pressurized Marwa
- Gate Valve

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Tradeoffs and priorities

- High crop productivity
- Low water quality
OBJECTIVE

Within the framework of Mad4water project and its objective to convert the traditional Marwas into optimized pipes, equipped with hydrants that supply water to downstream gated pipes, provided with calibrated nozzles and feeding fields furrows. The second objective of this thesis is aiming to Assess the performance of innovative self compensating gated pipe technology according to furrow irrigation design and management criteria.
INTEGRATING THE EFFICIENCY CHAIN

\[ Q = 0.8 \text{ l/s}; \]
\[ 0.1 \leq H_{\text{bar}} \leq 0.5 \]

Hydrant 20L/s

Lifting point from Branch canal

Mesqa: \( \phi \) (315-355 mm) served area 20 – 80 ha

Marwa: \( \phi \) (200-225 mm) L (250-400m) served area 2 – 4 ha
Gated pipe systems
Normal outlets Vs. self compensating outlets

Theoretical analysis of Gated pipe outlets

- Mass continuity

\[ \frac{Q_n}{Q_p} = \frac{Z_n}{Z_p} \]

- Energy conservation

\[ h_p + h_{p2} + Q_p = h_n + Q_n \]

- Pipe friction

- Gate outflow characteristic

\[ Q_n = C_d A_n \sqrt{2gh_p} \]

\[ Z_p + \frac{V_p^2}{2g} + h_p = Z_n + \frac{V_n^2}{2g} + h_n \]
Furrow irrigation - Gated pipe systems

Diagram showing the recession curve, depletion phase, wetting phase, and advance phase with labeled time of cutoff and recession time.
Materials & Methods

Simulation
A traditional furrow irrigation event was simulated using WinSrfr, OptGate to design the outlet.

Network Design
The network was designed according to the maximum flow velocity, and was divided into auto-calibrated and conventional furrow irrigation, with drainage canal and 2 connected reservoirs to calculate SRO.

Calibration of the outlets
The self-compensating gated pipes will be tested under different upstream operating pressures (2, 3, 4, 5 m) and the pipe DU will be calculated.

Perform irrigation events
Validation using both systems and comparative assessment by: DU, Ea, SRO, DPR, Er.

Comparative assessment
Experimental field

Drainage canal

Reservoirs
Performance Indicators
(Gated Pipe network)

\[ DU = \frac{\text{average low quarter discharges}}{\text{average discharge}} \times 100 \]

Energy losses (kJ) = \[ \frac{Q (H_{UP} - h_n)}{\eta} \times 9.6 T \]

- \( Q \): Discharge m³/hr
- \( H_{UP} \): Upstream head (m)
- \( h_n \): Downstream head (m)
- \( \eta \): Pump efficiency
- \( T \): Operating time (hrs)
Performance Indicators
(Furrow irrigation event)

\[ DU = \frac{\text{Average infiltrated depth in the 25% of the field less irrigated}}{\text{Average infiltrated depth}} \times 100 \]

\[ Ea = \frac{\text{Volume of water retained in the roozone}}{\text{Volume of applied irrigation water}} \times 100 = \frac{V_{ZR}}{V_T} \times 100 \]

\[ DPR = \frac{\text{Volume of water lost to deep percolation}}{\text{Volume of applied irrigation water}} \times 100 = \frac{V_{DP}}{V_T} \times 100 \]

\[ SRO = \frac{\text{Volume of water lost to surface runoff}}{\text{Volume of applied irrigation water}} \times 100 = \frac{V_{SRO}}{V_T} \times 100 \]
Expected Results

- Irrigation Network:
  - Increasing the Gates distribution uniformity (GDU) along the pipe
  - Slightly Higher energy consumption compared to conventional gated pipes
  - Enhancing the management flexibility and control of the overall distribution system due to shorter, more precise irrigation events

- On Farm:
  - Increasing the on farm application efficiency (Ea) by achieving higher (SDU) in lower irrigation time for each event, reducing (SRO), reducing the direct soil evaporation component and slightly reduce deep percolation

- Environmental Impact:
  - Reducing the surface runoff (drainage) therefore, providing more fresh water upstream and improving the overall water quality
Thank You

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