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Cost-centric innovations to address Water-Agriculture nexus challenges in Egypt: Research Status Analysis

Youssef Brouziyne[1], *Eman* Eldeeb[2], *Roaya* Abdoun[3], *Oumaima* Attar[4], *Ikram* Moumane[5,6], *Omnia* El Bergui[5,6], *Mohamed Amine* Benaly[4], *Imane* El Bakali[6], *Asma* Abou Ali[7], *Yassine* Ez-zaouy[4], *Aziz* Abouabdillah[5], *Rachid* Harbouze[6], *Souad* Haida[8], *Lahcen* Benaabidate[9]

[1]International Water Management Institute (IWMI), MENA Office, Giza 12661, Egypt
[2]Department of Agricultural and Biosystem Engineering, North Dakota State University, Fargo, ND 58105, United States of America
[3]Vegetable Crops Department, Faculty of Agriculture, Cairo University, Giza 12613, Egypt
[4]International Water Research Institute, Mohammed VI Polytechnic University (UM6P), Ben Guerir, Morocco
[5]Ecole Nationale d'Agriculture de Meknès, Meknès, Morocco
[6]Institut Agronomique et Vétérinaire Hassan II, Rabat, Morocco
[7]Laboratoire de Géologie Appliquée et Géo-Environnement, FSA - UIZ, Agadir, Morocco
[8]Lab. Natural Resources & Sustainable Development, Faculty of Sciences, Ibn Tofail, University, Kenitra, Morocco
[9]Laboratory of Functional Ecology and Environmental Engineering, Faculty of sciences and Techniques, University of Sidi Mohamed Ben Abdellah, Fez, Morocco

Abstract. High costs associated with technology adoption can be a barrier against the improvement of water use in agriculture. Therefore, interventions must be not only technically feasible but also financially affordable and accessible to farmers. To understand the current situation of research in low-cost (and cost-effective) water solutions for effective management of agricultural water challenges in Egypt. A total of 19 peer-reviewed papers were obtained from systematic research on various databases, the employed keywords are: "Egypt" AND "irrigation" AND "low cost" OR "low-cost" OR "cost-effective" OR "cost-effective". Based on the analysis of the selected studies, many low-cost technologies and techniques are applied in the Egyptian Delta on-farm levels, such as using low-cost soil moisture sensors attached to a smart monitoring unit operated by Solar Photo Voltaic Cells (SPVC), wireless sensor network in cultivating the potato crop, flexible on-field irrigation, cut-off irrigation, and Pressurized Irrigation Systems. The proposed solutions can help improve water use efficiency, increase crop yields, reduce the cost of irrigation, improve the quality of irrigation water, and promote sustainable agricultural practices. The economic analyses and feasibility studies presented in these papers provide valuable insights for policymakers and stakeholders in making informed decisions about water use and agricultural practices.

1 Introduction

Low-cost irrigation methods have gained increasing attention as a sustainable solution to address the challenges of water scarcity and high energy costs in the agricultural sector. The adoption of these low-cost irrigation methods can help small-scale farmers to access irrigation technologies that are affordable and effective, increasing their productivity and improving their economic well-being. Increasing the efficiency of water use and management at all levels and increasing farming productivity while conserving the resource base are the some of the important objectives of both the National Water Resources Plan 2017 [1] and the Government of Egypt's Strategy for Sustainable Agricultural Development 2030 [2].

In the context of water efficiency interventions within farmer communities, particularly in regions like Egypt's rural Delta area, where economic constraints significantly influence decision-making and the purchasing powers are comparatively low, the consideration of costs is paramount. Implementing water efficiency measures must align with the economic realities of farmers, many of whom operate on small-scale and subsistence-based farming models. Any intervention that fails to account for the economic aspect risks being impractical or unsustainable for these communities. High costs associated with technology adoption or infrastructure development can act as barriers, preventing widespread implementation. Therefore, interventions must be not only technically feasible but also financially viable, offering solutions that are affordable and accessible to farmers. By carefully considering the economic implications and ensuring cost-effectiveness, water efficiency interventions can have a more significant and lasting impact on improving agricultural productivity, livelihoods, and overall sustainability in such regions of the global south. This systematic review study attempts to assess the baseline in terms of research and development of low-cost (or cost-effective) water solutions for effective management of agricultural water challenges in Egypt.

2 Methodology

To assess the status of research in cost-effective and low-cost irrigation in Egypt, search engines were used to search manually to find peer reviewed papers published between 2010 and 2023 in English. A total of 19 papers were obtained from Google Scholar, Elsevier and Springer. The keywords employed to obtain the total number of papers to be analysed are "Egypt" AND "irrigation" AND "low cost" OR "low-cost" OR "cost-effective" OR "cost-effective." All papers were checked to ensure they included the keywords: Egypt, irrigation, and low-cost.

3 Results

The selection process highlighted 19 published papers complying with the set criteria; the table 1 represent the selected articles.

Table 1. The selected studies after selection process.

Study number	Technology type	Addressed issue(s)	Reference, authors and year of publication
1	Soil moisture sensor solar cells smart monitoring unit	water consumption (irrigation): monitoring of moisture content in the root zone area water scarcity	[3] (Okasha, A. M., et al.2021)
2	The cost of the flexible on-field irrigation and the traditional—drip and sprinkler—systems	water shortage equitable distribution	[4] (Abdel-Hamid, M., and Hanaa M. A., 2022)
3	Low concentrated photovoltaic (LCPV)	water scarcity high price of pumping m3 of water Cost of diesel	[5] (Soliman, A. W., Ayman H. N., and Ahmed M. S., 2017)
4	Use of electricity instead of diesel	water scarcity optimum utilization of the limited water resources	[6] (Abou El-Hassan, W. H., et al., 2015)
5	Water quality monitoring program	water scarcity agricultural drainage water reuse	[7] (Ashour, E. Bakenaz Z., and Elshemy, M., 2021)
6	Low-cost sand filter	Water shortage Drainage reuse	[8] (Sabry, T. I-M., El-Gendy S., and Sayed A., 2021)
7	Cut off irrigation	Water shortage limited Water Supply	[9] (Khalifa, R. M., and Ghannam M., 2021)
8	Low-cost sand filter	water deficit	[10] (Ismail, Khaled AI, et al. 2020).
9	Integrated solar power system for greenhouses irrigation system	Water shortage mixed water	[11] (Okasha, E-S., Hamdy El Awady M., and El Ghetany H., 2020)
10	Capacitive de-ionization (CDI)	Freshwater scarcity	[12] El Shafei, M. and Seleym, A. 2017)
11	Solar energy	shortage in electricity and water access Delivering and using diesel is facing different economic and environmental risks	[13] (Shouman, E. R., Hesham E., and Bakhoum E- S., 2018)
12	The computational program (Trickle Irrigation System Design, TISD)	water scarcity low yields	[14] (Khalifa, W. M., 2022)
13	CDI desalination technology	water scarcity	[15] (Elshafei, M., et al., 2020.
14	Wireless sensor network	water scarcity Low production size and quality causing shortcomings in their export size	[16] (Abd El-kader, S. M., and El-Basioni, M. M., 2013

15	Chemically enhanced primary treatment (CEPT)	water scarcity Wastewater treatment	[17] (Esawy Kasem, M., 2015)
16	Lined canal and buried pipes	severe shortage of water at the tail reaches low conveyance efficiency high operational cost excessive water loss to drains.	[18] (Osman, E-A. M., et al., 2016)
17	Pressurized irrigation systems	low income and yield	[19] (El-Hagarey, M. E., Hani A. M., and Gyuricza, C.,2015)
18	Optimize a stand-alone battery-less PV water pumping system (PVWPS).	Alternative energy sources Storing water via water tank instead of storing electrical energy.	[20] Rezk, H. 2016)
19	Mechanized raised-bed wheat production	food security needs	[21] (Alwang, J. et al. 2018)

The selected papers propose various low-cost irrigation methods to address the challenges facing Egyptian farmers related to irrigation and agricultural water in general. most of experiments or demonstrations were in one of the three governorates: El-Behira, Kafr El-Sheikh, and Al Sharkia; Which are all located in the Nile Delta region of Egypt. They share a common geographical location in the northern part of the country and are bordered by the Mediterranean Sea to the north. The three governorates are the major agricultural regions in Egypt and faces challenges related to water scarcity and irrigation systems efficiency.

In terms of crops concerned by these research works, all the following crops were covered by one study: potato, olive trees, cotton, sesame, faba bean, pomegranate trees, citrus trees, clover, sugar beet, maize and rice. However, tomato, wheat and vegetables such as eggplant were covered by 2, 3 and 2 papers respectively, which can be explained by the socio-economic importance of these crops as well as their importance from irrigation water management perspective in Egypt.

Results

3.1 The addressed agricultural water challenges

The19 selected papers addressed various challenges related to irrigation and agriculture in Egypt, with a focus on limited access to water, and/or high cost of conventional irrigation methods, poor water quality and soil productivity, and environmental impacts.
Limited access to water and water scarcity are major challenges facing Egyptian farmers, as water resources are becoming increasingly scarce due to population growth and climate change. Six papers out of the total selected papers address this challenge. The papers propose solutions such as wireless sensor network technology, solar energy, capacitive deionization desalination technology, trickle irrigation systems, and battery-less photovoltaic water pumping systems to help farmers overcome the challenge of limited access to water and to make irrigation precise. These technologies can help farmers increase crop yields while using less water, thus improving water use efficiency and ensuring food security.
The high cost of conventional irrigation methods is another major challenge facing Egyptian farmers. Four papers out of the total selected papers address this challenge. The papers

propose solutions such as solar energy, lined canals, buried pipes, and flexible on-field irrigation systems to help farmers reduce the cost of irrigation.
Poor water quality is a significant challenge facing Egyptian farmers, as irrigation water is often contaminated with pathogens and heavy metals. Four papers out of the total selected papers address this challenge. The papers propose solutions such as sand filtration units, capacitive-based soil moisture sensors, and low-cost technology for wastewater treatment to help farmers improve the quality of irrigation water.
Soil productivity is a critical factor for agricultural sustainability, and maintaining soil productivity is a significant challenge facing Egyptian farmers. Two papers out of the total selected papers address this challenge. The papers propose solutions such as furrow irrigation and mulching to help farmers improve soil productivity and reduce water loss due to evaporation.
Environmental impacts of irrigation systems are significant, and policymakers need to make informed decisions about sustainable water use and agricultural practices. Four papers out of the total selected papers address this challenge. The papers propose solutions such as assessing the environmental and economic impacts of irrigation systems, integrated solar power systems for greenhouses, and designing low-cost capacitive-based soil moisture sensors to help policymakers make informed decisions about sustainable water use and agricultural practices.

3.2 The investigated solutions

The 19 selected papers propose various solutions to address the challenges facing Egyptian farmers related to limited access to water, high cost of conventional irrigation methods, poor water quality, water scarcity, soil productivity, and environmental impacts while considering the economics.

Four papers out of the total selected papers propose solutions that utilize solar energy to power irrigation systems. The papers investigate the feasibility and economic viability of using solar energy for irrigation in Egypt. The key results show that the use of solar energy can significantly reduce the cost of irrigation and improve water use efficiency, particularly in remote areas where access to electricity is limited.
Six papers out of the total selected papers propose solutions that utilize various low-cost filtration and treatment technologies to improve the quality of irrigation water. The papers investigate the effectiveness of sand filtration mixed with other filtration media, capacitive deionization desalination technology, constructed wetlands, and low-cost technology for wastewater treatment. The key results show that these technologies can effectively remove contaminants from irrigation water, improve crop yields, and reduce the risk of disease transmission.
Three papers out of the total selected papers propose solutions that utilize on-field irrigation systems to improve water use efficiency and reduce water loss due to evaporation. The papers investigate the effectiveness of flexible on-field irrigation systems, trickle irrigation systems, and furrow irrigation. The key results show that these systems can significantly reduce water use and improve crop yields (up to 30%).
Two papers out of the total selected papers propose solutions that utilize integrated solar power systems and low-cost capacitive-based soil moisture sensors to improve irrigation management in greenhouses. The papers investigate the effectiveness of these technologies in improving water use efficiency and reducing the cost of irrigation in greenhouse production. The key results show that these technologies can significantly reduce water use (up to 37%) and improve crop yields (up to 18%).

Five papers out of the total selected papers investigate the economic viability and feasibility of various other irrigation technologies and practices in Egypt. The papers investigate the economic and food security benefits associated with raised-bed wheat production, the cost benefits analysis of flexible on-field irrigation systems, the economic analysis of using traditional fuel and solar energy to power irrigation pumps, the economic feasibility analysis of pressurized irrigation systems for wheat under desert environmental conditions, and the assessment of cost-effective alternatives for improving irrigation systems in the Nile Delta.

4 conclusion

In conclusion, the array of challenges facing Egyptian farmers in irrigation and agriculture has been thoroughly examined through the lens of 19 selected papers. These challenges, encompassing limited access to water, high costs of conventional methods, poor water quality, soil productivity concerns, and environmental impacts, underscore the complexity of sustainable agricultural practices in Egypt.

The proposed solutions showcased in these papers offer promising avenues for addressing these challenges while considering economic feasibility. From harnessing solar energy to power irrigation systems and implementing low-cost filtration and treatment technologies to improve water quality, to deploying on-field irrigation systems and integrated solar power systems for greenhouses to enhance water use efficiency, the potential for innovation and sustainable practices in Egyptian agriculture is evident.

Furthermore, the economic analyses and feasibility studies presented in these papers provide valuable insights for policymakers and stakeholders in making informed decisions about water use and agricultural practices. By embracing these innovative solutions and adopting sustainable approaches, Egyptian farmers can mitigate the impact of water scarcity, enhance crop productivity, and contribute to long-term agricultural sustainability in the region.

Overall, the findings and recommendations put forth in these papers underscore the importance of collaborative efforts among researchers, policymakers, and farmers to address the pressing challenges in agricultural water management and pave the way for a more resilient and sustainable agricultural future in Egypt.

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