J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol.14 (12): 423 - 430, 2023

Journal of Soil Sciences and Agricultural Engineering

Journal homepage & Available online at: www.jssae.journals.ekb.eg

Effect of Deficit Irrigation under Developed and Traditional Irrigation Systems Using Solar Energy on Cost and Productivity in Clay Soil.

Mohammed, A. S. H.[1]*; A. H. Awwad[1] and M. M. A. Shabana[2]

[1] Irrigation and Drainage Engineering Department, Agricultural Engineering Research Institute (AEnRI), Agricultural Research Center (ARC), Giza, Egypt.

[2] Soils, Water and Environment Res. Inst., Agricultural Research Center (ARC), Giza, Egypt

Cross Mark

ABSTRACT

This research was conducted during the 2021-2022 agricultural season a private farm in Kafr-ElSheikh Governorate to evaluate the impact of using a renewable energy source (solar energy) for developed irrigation system in old lands by comparing it to using non -renewable energy sources (electric and diesel) for the same developed irrigation system and the traditional irrigation system to achieve sustainable agricultural development, in addition to the effect of deficit irrigation on plants to improve crop productivity and rationalize irrigation water, which leads to improving the agricultural environment.The research depends on the economic evaluation like total costs of irrigation, energy, agricultural costs also the water unit productivity for winter crops (wheat), the research also depends on data collected from the National Irrigation Development Project in cultivating the wheat crop in Kafr El-Sheikh Governorate.The use of solar energy with developed irrigation system has proved to be better than electric and diesel energy, in addition to being clean energy that does not pollute the environment, inexpensive and available.Deficit irrigation by a ratio 80% of full irrigation, as the decrease in productivity and costs can be overlooked in exchange for the saving in water.The return on water unit, the total revenue and the net return were greater under developed irrigation systems with solar energy (100% water applied) which were 11.74 LE/m^3, 18310.6 LE/fed and 10120.6 LE/fed respectively. In addition to saving water and land as a result of using the developed irrigation system.

Keywords: developed, traditional, electric, solar, energy.

INTRODUCTION

Egypt is living in a new era of challenges facing it economically, politically, and socially. The most important of these challenges is water policy. It plays an important role in food security, as Egypt has been exposed to a water war (not long ago). The threat to the waters of the Nile Basin. The pollution of the Nile River water facing the agricultural sector is one of the most important challenges, as is the waste of water using traditional irrigation methods, especially in the old lands of the Delta, as the efficiency of traditional surface irrigation may reach 50% due to the low regularity of water distribution, deep filtration, and run off. The result is a decrease in production

It is important to find water sources other than Egypt's share of the Nile water to increase agricultural land by cultivating strategic crops that require additional amounts of water by conserving water and increasing the efficiency of irrigation water by using developed irrigation systems. The best and only solution is not only cultivating new lands and desert, but there are other methods that can be directed as a development policy for the ancient delta region, which still uses traditional irrigation systems.

Qianwen-Zhang *et al.*, (2023) said that the problem of energy shortages and lack of water sources has greatly contributed to the problem of developing sustainable agriculture. Promoting green operation and low energy consumption of water-saving irrigation systems have become inevitable Requirements for sustainable agricultural production. Also added is the feasibility of using coupled solar energy using compressed air to provide energy for pressure irrigation systems, it provides a new approach for the effective combined application of distributed solar energy resources and irrigation technology.

Joshua Wanyama, *et al.* (2023) used the Smart Irri-Kit features a solar-powered system that has the potential for use in smallholder agriculture this makes it attractive to the younger generation but also to potential farmers who may not be full-time on the farm. The Smart Irri-Kit features a solar-powered system that drives a water pump and microcontroller mounted on a movable frame. The design, development, and evaluation of a solar-powered smart irrigation control system kit, referred to as the Smart Irri-Kit identified. It provides detailed insights into the system components, methodology, results, and future directions, underscoring the potential impact of this innovative technology on the agricultural sector. The kit combines the advantages of solar power and intelligent irrigation scheduling to create an efficient and sustainable solution for agricultural irrigation (Lozoya *et al*. 2014, Fernandez, 2017).

The growing need for sustainable agricultural Practices and the development of a solar-powered intelligent irrigation control system set has a promising future. By harnessing solar energy, this kit can operate independently, reducing reliance on traditional energy sources and reducing operating costs for farmers. Also, smart controls deliver precise water distribution based on real-time soil moisture data, optimizing water use and enhancing overall irrigation efficiency. Although irrigation control strategies have been investigated in recent years (Abioy *et al.* 2023).

*** Corresponding author.**
E-mail address: ahmedsalahhassan1@yahoo.com
DOI: 10.21608/jssae.2024.253181.1207

The consumption of water resources for irrigation is a major global challenge for sustainable agriculture for human food and animal feed production. Therefore, it is necessary to use pipes and pumps to transport water, and it is known that pumps operate either on fossil fuels such as gasoline and diesel or on electric power. These are methods that increase pollution and lack of electricity distribution. It is necessary to turn to using renewable energy resources such as solar energy to operate electric water pumps for irrigation purposes. The present paper proposes a design for a standalone transformer-less DC/AC converter powered by PV panels (Mustafa *et al.* 2023).

Pardo *et al*., 2019 and Tamer *et al*., 2019 demonstrated the feasibility of achieving the provision of new energy resources besides traditional energy, the use of clean photovoltaic energy to drive the system is Another measure. Integrates irrigation with solar-powered sprinklers the dual advantages of clean energy and high-efficiency water saving, which is conducive to promoting the development of water and energy saving in agricultural production, it has attracted widespread attention last few years.

Electric pumps operate by solar energy like any other available and commonly used energy water pump. The biggest difference is that the pumps are solar-powered. They are solar-powered and do not require traditional oil-based fuel or an external energy source (from utilities) to power them Water (Kumar.*et al*. 2018).

This paper presents the design, development, and evaluation of a solar-powered smart irrigation control system kit, referred to as the Smart Irri-Kit. It provides detailed insights into the system components, methodology, results, and future directions, underscoring the potential impact of this innovative technology on the agricultural sector. The kit combines the advantages of solar power and intelligent irrigation scheduling to create an efficient and sustainable solution for agricultural irrigation (Lozoya *et al* 2014 and Fernandez, 2017).

Awwad *et al.* (2016) made a study to evaluate the effect of modified surface irrigation in old land through improving Mesqas (buried pipeline) and Marwas of irrigation systems developer on the properties of the soil and its effect on (productivity) and save of irrigation water leading to improved agricultural environment, also the economic evaluation in as important indicator which includes the productivity per unit of irrigation water for wheat crop maize crop and the study also includes the technical evaluation in terms of water losses in delivery and distribution for developed Mesqa and Marwa, and showed that the agricultural land was saved through using buried pipes instead of traditional Mesqa ranged from about 2.1 % to 3.7 % with developed surface irrigation systems for Mesqa and Marwa respectively, while the average application efficiencies for irrigation systems developer by Mesqa and Marwa were ranged from about 61.5% to 77% and ranged from about 65% to 84.4 % respectively and it was ranged from about 53 % to 66.4 % under traditional surface irrigation according to type of crop. The value of (WUE) in improved irrigation systems for Mesqa and Marwa were 1.52 and 1.38 kg/m3 respectively for wheat and it was 1.16 kg/m3 under traditional surface irrigation.

Saad-Eddin *et al* (2016) showed that the saved agricultural land through using buried pipes as improved Mesqa ranged from about 2.74 % to 2.067 % and in the lining canal it ranged from1.33 % to 1.04 % compared with traditional earth Mesqa which were occupied by the channels and ridges. Average conveyance efficiencies were as 82.4%, 92.7%, and 98.38% for traditional earthen, lining and buried pipes Mesqas respectively. Average application efficiencies were 81.5 % under improved On-farm surface irrigation (Precession laser land leveling) compared with 59% under traditional surface irrigation. Irrigation time decreased 31.39% by using improved surface irrigation compared with traditional surface irrigation. The productivity of wheat and sorghum increased 10.81% and 10.44 % respectively under improved surface irrigation compared with traditional surface irrigation. The values of field water use efficiency (FWUE) for wheat and sorghum were 1.49 kg/m^3 and 1.08 kg/m^3 under improved surface irrigation compared with 0.87 kg/m3 and 0.631 kg/m3 under traditional surface irrigation respectively.

This research was conducted to evaluate the impact of using a renewable energy source (solar energy) for developed irrigation system in old lands by comparing it to using non-renewable energy sources (electric and diesel) for the same developed irrigation system and the traditional irrigation system to achieve sustainable agricultural development, in addition to the effect of deficit irrigation on plants to improve crop productivity and rationalize irrigation water, which leads to improving the agricultural environment.

MATERIALS AND METHODS

A field experiment was conducted during the winter season of 2021/2022 at privet farm in Kafr-ElSheikh Governorate, Egypt. The outdoor experimental design was a randomized complete design, with eight treatments for tested variables for flood irrigation systems shown in Table (1). Figure 1 to Figure 4 shows the layout of out-door experiments under the traditional irrigation operated by a diesel engine (A), a developed irrigation driven by a diesel engine (B), a developed irrigation using electric energy (C), and a developed irrigation using solar energy (D), respectively.

Design of developer irrigation system

Marwa line which was opened one valve along the line mesqas discharge of 20 L/sec., until the finishing of the irrigation area then closed the hydrant and open the next valve according to the water scheduling with the rest of the space within the control of the station and was calculated losses of pressure at the ends of the valves mesqas. The type of the main valves was butterfly valve under study area.

Specifications of pump stations

Figure (5) shows diesel pump in the traditional and the developed irrigation system, which is the prevailing system in the delta, (discharge 70 m3/h, engine capacity 5 HP, 1000 rpm, and head 5 meters Figure (6) shows the electric pump in the developed irrigation system, which contains (a discharge of 30 l/s, a 10 horsepower motor with 1440 rpm/minute, and a head of 13 meters).

On the other hand, Figure (7) shows a solar pump station in the developed irrigation system. Its specifications are a 10-horsepower, 380-volt, 3-phase, 4/5-inch electric motor and a 17-meter lifter with the discharging of 170 cubic meters per hour. The 36 panels of 260 watts, with a total of 9.36 kW. On a metal structure installed the irrigation room on a 13-meter-long with Kharasan base, mounted on 2 concrete columns above the irrigation room, and containing a 10-kilowatt inverter to reverse the direct current into a 3-phase alternating current to operate the motor.

Table 1. The experimental treatments

Symbol	A_{100}	A_{80}	B_{100}	B_{80}	C_{100}	C_{80}	D_{100}	D_{80}
The system	traditional irrigation	traditional irrigation	developed irrigation	developed irrigation	developed irrigation	developed irrigation	developed irrigation	developed irrigation
Percentage water applied (%)	100	80	100	80	100	80	100	80
Energy source	diesel	diesel	diesel	diesel	electric	electric	solar	solar

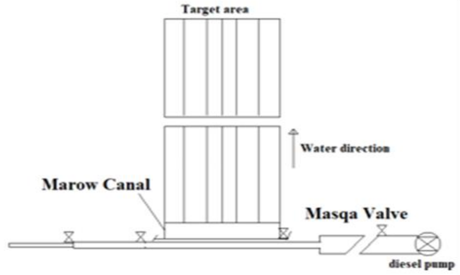

Fig. (1): Layout of the traditional irrigation system with diesel energy (A)

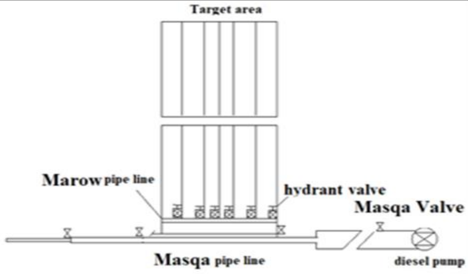

Fig. (2): Layout of the developer irrigation system with diesel energy (B)

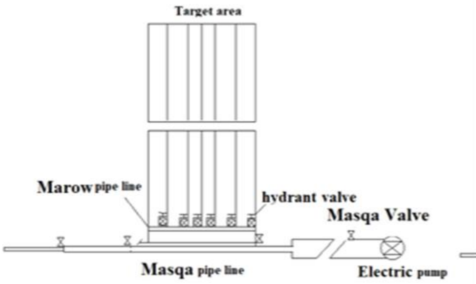

Fig. (3): Layout of the developer irrigation system with electric energy (C)

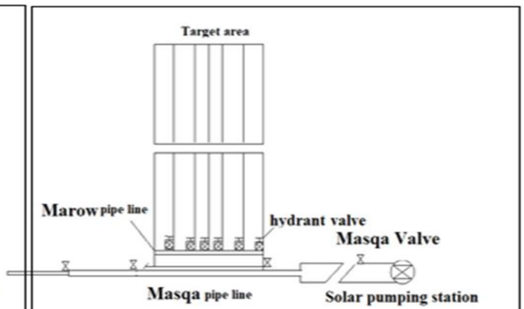

Fig. (4): Layout of the developer irrigation system with solar energy (D)


Pump of traditional irrigation system


Pump of developed irrigation system.

Fig. (5): diesel pump station in the traditional and developed irrigation system.


Fig. (6): electric pump station in the developed irrigation system.


Fig. (7): solar pump station in the developed irrigation system.

Soil physical and chemical analysis

Samples of soils were collected from different depths and the following hydrophysical- chemical analysis was done according to Richards (1954) and Jackson (1967). Permanent wilting point (PWP) and field capacity (FC) were determined according to Klute (1986) by pressure membrane method double ring cylinder infiltrometer was used to measure the infiltration rate as described by Garcia (1978) before the cultivation and after the harvesting. The bulk density of the soil and total porosity of the different depths of soil profile (at four layers: 0-20, 20-40, 40-60 and 60-80 cm) were measured before the cultivation and after harvesting for all treatments by using the core sampling technique as described by Campbell (1994). Some physical and chemical properties of the soil experimental are shown in Table (2).

Table 2. Initial soil chemical and physical analysis of the experimental sites (0-80 cm) before sowing

Site	pH	EC	ESP	CaCo3	OM	Available NPK (mg/kg)			Texture class	F.C	PW.P	Bulk density	Total porosity	PR	IR
		dS/m		%	%	N	P	K		%	%	(g/cm^3)	%	N/cm^2	cm/h
1	8.12	3.79	12.22	2.41	0.93	45.25	6.68	247	Clayey	44.45	23.32	1.34	49.43	290	1.04
2	8.11	3.25	11.35	2.47	1.11	42.23	6.26	223	Clayey	44.73	23.49	1.33	49.81	240	1.12
3	8.09	3.33	11.48	2.45	1.17	44.36	6.52	238	Clayey	45.11	24.18	1.32	50.18	250	1.13
4	8.18	3.26	11.37	2.34	1.16	43.12	6.43	237	Clayey	44.84	23.75	1.33	49.81	240	1.11

pH =(in 1:2.5 soil: water suspension), EC= (Soil salinity) Electrical conductivity (in soil paste extract); ESP = Exchangeable sodium percentage, OM: Organic matter; FC: field capacity; PWP: permanent wilting point; PR: soil penetration resistance.; IR: infiltration rate.

Water Use Efficiency and water productivity

Water Use Efficiency (WUE) was calculated by the following equation according to Abd El -Rasool *et al*., (1971) and water productivity was calculated in kg m^{-3} for different irrigation systems according to Michael, (1978).

WUE=Yield (kg fed^{-1})/Water consumptive use (m^3 fed^{-1})..(1)

Applied water (AW)

Giriappa (1983) described and calculated the applied water (AW) as follows:

AW=IW+ER …….…………… ………… (2)

Where, IW: irrigation water applied, ER: effective rainfall.

Save of water

Save of water was expressed in terms of volume ratio. The ratio of applied water volume to improved irrigation system as related to the volume of applied water in the traditional irrigation system was calculated using the following equation:

Water saving (%) = [(v_1 – v_2) / v_1]100 …… (3)

Where, V1: water volume per season under improved surface irrigation system, V_2: water volume per season under traditional irrigation system.

Calculation the economic variables

The economic variables was expressed in terms of Net return, Unit profitability, Return on the invested pound, Rate of return on variable costs and Return on water unit were calculated using the following equations according to https://agri.aljeelalmoshreq.com.

$$\text{Net return (LE/fed)} = \text{Total revenue (LE/fed)} - \text{Total cost (LE/fed)} \ldots\ldots\ldots\ldots (4)$$

$$\text{Unit profitability (LE/}Erdab\text{)} = \frac{\text{Net return (LE/fed)}}{\text{Production yield (Erdab/fed)}} \ldots\ldots\ldots\ldots (5)$$

$$\text{Return on the invested pound (LE/fed)} = \frac{\text{Net return (LE/fed)}}{\text{Total cost (LE/fed)}} \ldots\ldots\ldots\ldots (6)$$

$$\text{Return on water unit (LE/m\^{}3)} = \frac{\text{Total revenue (LE/fed)}}{\text{Water applied (m\^{}3/fed)}} \ldots\ldots\ldots\ldots (7)$$

$$\text{Rate of return on variable costs (\%)} = \frac{\text{Total revenue (LE/fed)}}{\text{Total variable costs (LE/fed)}} \times 100 \ldots\ldots (8)$$

RESULTS AND DISCUSSION

Quantity of irrigation water (m^3/fed)

Data in Figures (8 and 9) showed that the water consumption (using diesel energy) with 100% and 80% water applied under traditional irrigation systems were 2465 and 1972 m^3/fed respectively for a decrease amounting to 493 m^3/fed. However, the water consumption (using diesel, electric and solar energy) with 100% and 80% water applied under developed irrigation system was 1560 and 1248 m^3/fed respectively, with a decrease amounting to 312 m^3/fed.

Data in Figure (9) demonstrated that the water consumption (with 100% water applied) by using diesel energy under a traditional irrigation system was 2465 m^3/fed while by using diesel, electric, and solar energy for a developed irrigation system was 1560 m^3/fed with a decrease amounting to about 905 m^3/fed by reduction ratio 58.01% compared to a traditional irrigation system with diesel energy.

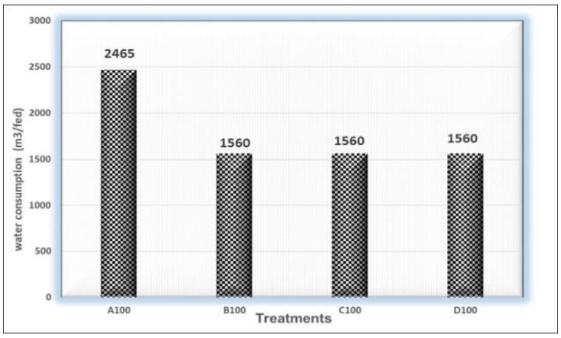

Figure 8. Water consumption (m3/fed) under all treatments

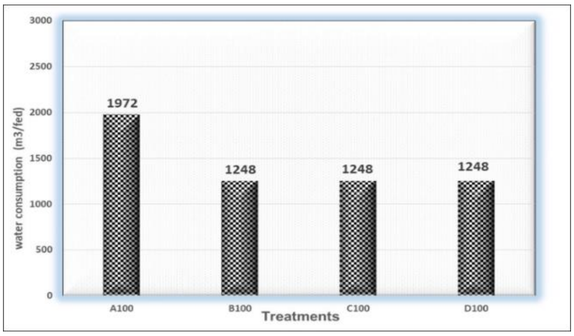

Figure 9. Water consumption (m3/fed) under 80% water applied

On the other hand, data in Figure (9) showed that the water consumption (with 80% water applied) by using diesel energy for a traditional was 1972 m^3/fed while by using diesel, electric and solar energy under developed irrigation system were 1248 m^3/fed with a decrease amounting to 724 m^3/fed by reduction ratio 36.7% compared to traditional irrigation system with diesel energy.

Production yield of wheat crop (kg/fed)

Data in Figures (10 and 11) showed that the production yield (using diesel energy) with 100% and 80% water applied under traditional irrigation system were 3048 and 2400 kg/fed respectively with a decrease amounting to 648 kg/fed, while the production yield by using diesel, electric and solar energy (with 100% water applied) under developed irrigation system were 3225, 3300 and 3350 kg/fed respectively, while the production yield by using diesel, electric and solar energy (with 80% water applied) under developed irrigation system were 2550, 2600 and 2625 kg/fed respectively with a decrease amounting to 675, 700.5 and 675 kg/fed respectively.

Data in Fig (11) showed that the production yield (using diesel energy) with 100% and 80% water applied under traditional irrigation systems were 3.048 and 2.4 Ton/fed respectively with a decrease amounting to about 648 kg/fed, while the production yield by using diesel, electric and solar energy (with 100% water applied) for the developed irrigation systems were 3225, 3300 and 3350 kg/fed respectively, while the production yield by using diesel, electric and solar energy (with 80% water applied)for the developed irrigation system were 2550, 2600 and 2625 kg/fed respectively with a decrease amounting to about 675, 700.5 and 675 kg/fed respectively.

Data in Figures (10 and 11) presented that the production yield (using diesel energy) with 100% and 80% water applied under developed irrigation systems were 3225 and 2550 kg/fed respectively, with a decrease amounting to 600 kg/fed, while the production yield (using electric energy) with 100% and 80% water applied under developed irrigation system were 3300 and 2600 kg/fed respectively with a decrease amounting to 700.5 kg/fed, and the production yield (using solar energy) with 100% and 80% water applied under developed irrigation system were 3350 and 2625 kg/fed respectively with a decrease amounting to 724.5 kg/fed,

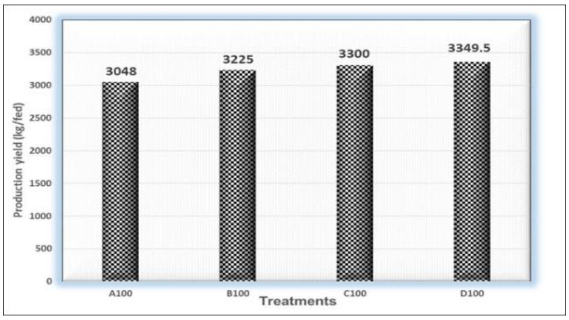

Figure 10. Production yield (kg/fed) under 100% water applied

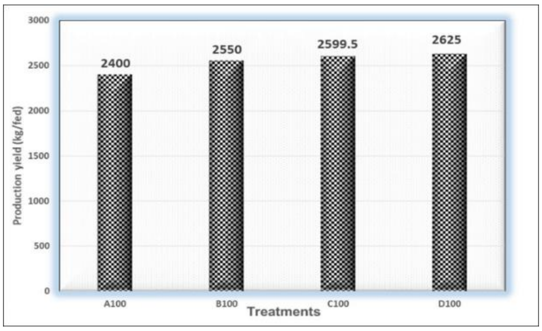

Figure 11. Production yield (kg/fed) under 80% water applied

Water unit productivity of wheat crop (kg/m^3)

The results in Figures (12 and 13) showed that the water unit productivity of the wheat crop (by using diesel, electric and solar energy) with 100% water applied was decreased compared with 80% water applied under all treatments by reduction ratio from 1.44 % to 2.3%.

Data in Figures (12 and 13) showed that the water unit productivity of the wheat crop (by using diesel energy) with 100% water applied was 1.24 kg/m^{3}under traditional irrigation system while using diesel, electric and solar energy which were 2.07 kg/m^3, 2.12 kg/m^{3}and 2.15 kg/m^{3}under developed irrigation system respectively, while (by using diesel energy) with 80% water applied was 1.22 kg/m^3 under traditional irrigation system compared with using diesel, electric and solar energy which were 2.04 kg/m^3, 2.08 kg/m^{3}and 2.1 kg/m^3 under developed irrigation system respectively.

There are two reasons to explain that increase in productivity and water efficiency first, the use of solar energy in the operating of irrigation pump, lead to the Stability of energy and the flow rate of water from the solar-pump, thereby increasing the operational efficiency of these pumps and thereby increasing the efficiency of water distribution and wheat productivity. On the one hand, irregularity of the flow rate of water from diesel pumps or cut of electricity from electricity pumps leads to decrease operational efficiency and consequently decrease of water distribution efficiency and decrease of wheat productivity, second, the amount of water used to irrigate the wheat crop using developed irrigation system decreased by 36.7% compared to traditional irrigation. Moreover, the use of 80% of irrigation requirement with developed irrigation system (reducing the amount of water applied to the wheat crop) leads to reduction of productivity at 80% under developed irrigation system with all types of energy used to irrigation pump.

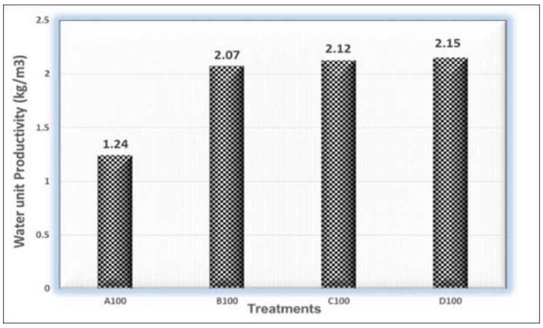

Figure 12. Water unit productivity (kg/m3) under 100% water applied

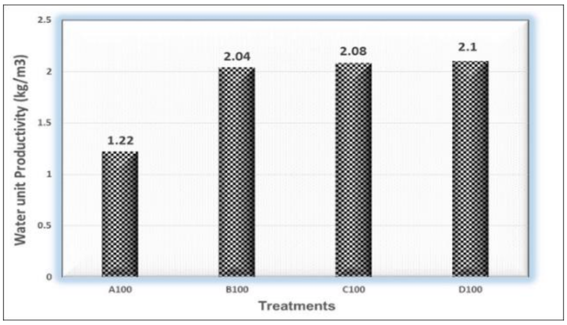

Figure 13. Water unit productivity (kg/m3) under 80% water applied

Economical evaluation

This part Includes comparing the productive and economic efficiency of the wheat crop under two methods of surface irrigation (traditional and developed) for non-renewable energy (diesel and electricity) and renewable energy (solar energy) by using the following indicators:

Costs of fuel (LE/fed per season)

Data in table (3) showed that Costs of fuel (using diesel energy) with 100% and 80% water applied under traditional irrigation system were 382 LE/fed and 300 LE/fed respectively with a decrease amounting to 82 LE/fed, while Costs of fuel (using diesel, electric and solar energy) with 100% and 80% water applied under developed irrigation system there are no significant differences between 100% and 80%.

On the other hand, Data in table (3) showed that Costs of fuel (by using diesel energy) with 100% water applied was 382 LE/fed under traditional irrigation system while using diesel, electric and solar energy which were 302 LE/fed., 408

LE/fed and 210 LE/fed under developed irrigation system respectively, while (by using diesel energy) with 80% water applied was 300 LE/fed under traditional irrigation system compared with using diesel, electric and solar energy which were 287 LE/fed, 408 LE/fed and 210 LE/fed under developed irrigation system respectively.

Generally, Costs of fuel (LE/fed) under developed irrigation system with solar energy were lower than other treatments, taking into account that the development cost is fixed with all the developed irrigation treatments, which is 750 LE/fed/season (1500 LE/fed/year).

Table 3. Costs of fuel & Development costs (LE / fed / season)

Treatments	A_{100}	A_{80}	B_{100}	B_{80}	C_{100}	C_{80}	D_{100}	D_{80}
Costs of fuel (LE/fed/season)	382	300	302	287	408	408	210	210
*Development costs	-	-	750	750	750	750	750	750
Total	382	300	1052	1037	1158	1158	960	960

***Development costs: 1500 LE/fed/year or 750 LE/fed/season**

The total value of fertilization (LE/fed)

Data in Table (4) showed that the total value of fertilization for the wheat crop decreased from 2790 LE/fed under a traditional irrigation system (with diesel energy) to 2690 LE/fed for a developed irrigation system (diesel, electric and solar energy), with a decrease amounting to 100 LE/fed by reduction ratio 3.6% compared to traditional irrigation.

Table 4. Cost of Fertilization (LE / fed / season)

Treatments	A_{100}	A_{80}	B_{100}	B_{80}	C_{100}	C_{80}	D_{100}	D_{80}
Superphosphate	750	750	750	750	750	750	750	750
organic fertilizer	600	600	500	500	500	500	500	500
Nitrogen fertilizer (urea)	1440	1440	1440	1440	1440	1440	1440	1440
Total	2790	2790	2690	2690	2690	2690	2690	2690

The total value of production requirements (LE/fed)

Data in Table (5) presented that the total value of production requirements for the wheat crop decreased from 1090 LE/fed under a traditional irrigation system (with diesel energy) to 940 LE/fed under a developed irrigation system (diesel, electric and solar energy), with a decrease amounting to 150 LE/fed by reduction ratio 13.8% compared to traditional irrigation.

Table 5. Cost of production requirements (LE/fed/season)

Treatments	A_{100}	A_{80}	B_{100}	B_{80}	C_{100}	C_{80}	D_{100}	D_{80}
Pesticides	350	350	200	200	200	200	200	200
Wheat seeds	740	740	740	740	740	740	740	740
Total	1090	1090	940	940	940	940	940	940

The total value of agricultural operations (LE/fed)

Data in Table (6) showed the total value of agricultural operations for the wheat crop decreased from 1200 LE/fed under a traditional irrigation system (with diesel energy) to 850 LE/fed under a developed irrigation system (diesel, electric and solar energy), with a decrease amounting to 350 LE/fed by reduction ratio 29.2% compared to traditional irrigation.

Table 6. Cost of agricultural operations (LE/fed/season).

Treatments	A_{100}	A_{80}	B_{100}	B_{80}	C_{100}	C_{80}	D_{100}	D_{80}
Plowing	200	200	200	200	200	200	200	200
Fertilization	250	250	150	150	150	150	150	150
Cultivation	300	300	300	300	300	300	300	300
Irrigation	450	450	200	200	200	200	200	200
Total	1200	1200	850	850	850	850	850	850

Cost of human labor (LE/fed/season)

Data in Table (7) showed the total value of human labor for the wheat crop decreased from 1050 LE/fed under traditional irrigation system (with diesel energy) to 900 LE/fed under developed irrigation system (diesel, electric and solar energy), with a decrease amounting to 150 LE/fed by reduction ratio 14.3% compared to traditional irrigation.

Table 7. Cost of human labor (LE/fed/season).

Treatments	A_{100}	A_{80}	B_{100}	B_{80}	C_{100}	C_{80}	D_{100}	D_{80}
waste removal	750	750	650	650	650	650	650	650
Harvesting	300	300	250	250	250	250	250	250
Total	1050	1050	900	900	900	900	900	900

Cost of Automation work (LE/fed/season)

Data in Table (8) showed the total value of automation work for the wheat crop was the same under the traditional irrigation system (with diesel energy) and the developed irrigation system (diesel, electric and solar energies) which was 1850 LE/fed.

Table 8. Cost of automation work (LE/fed/season).

Treatments	A_{100}	A_{80}	B_{100}	B_{80}	C_{100}	C_{80}	D_{100}	D_{80}
Land leveling	200	200	200	200	200	200	200	200
Wheat thresher	1200	1200	1200	1200	1200	1200	1200	1200
Transport	450	450	450	450	450	450	450	450
Total	1850	1850	1850	1850	1850	1850	1850	1850

Total variable costs (LE/fed/season)

Data in Table (9) showed the total variable costs for the wheat crop under all treatments it ranged from 8190 LE/fed to 8388 LE/fed.

Table 9. Total variable costs (LE/fed/season).

Treatments	A_{100}	A_{80}	B_{100}	B_{80}	C_{100}	C_{80}	D_{100}	D_{80}
Cost of Fertilization	2790	2790	2690	2690	2690	2690	2690	2690
Cost of human labor	1050	1050	900	900	900	900	900	900
Cost of Automation work.	1850	1850	1850	1850	1850	1850	1850	1850
Agricultural operations.	1200	1200	850	850	850	850	850	850
Cost of production requirements.	1090	1090	940	940	940	940	940	940
Costs of fuel.	382	300	302	287	408	408	210	210
Development costs	-	-	750	750	750	750	750	750
Total variable cost.	8362	8280	8282	8267	8388	8388	8190	8190

Productive and economic efficiency

Table (10) shows the productive and economic efficiency of the wheat crop. It includes many indicators such as farm price, total revenue, net return, total variable costs, unit profitability, return on the invested pound, rate of return of variable costs and return on water unit.

Farm price (LE/Ton)

The results of Table (10) showed that the farm price of the wheat crop remained the same with all treatments under the traditional irrigation and developed irrigation systems, as it averaged 5466.66 LE/Ton.

Total revenue (LE/fed):

The results of table (10) showed that the total revenue of the wheat crop (by using diesel energy) with 100% water applied was 16662.4 LE/fed under a traditional irrigation system compared with using diesel, electric and solar energy under developed irrigation system which were 17630 LE/fed, 18040 LE/fed and 18310.6 LE/fed respectively by increasing ratio 5.8%, 8.26% and 9.9% compared to traditional irrigation.

While the total revenue (by using diesel energy) with 80% water applied was 13120 LE/fed under the traditional irrigation system compared with using diesel, electric and solar energy for developed irrigation system which were 13940 LE/fed, 14210.6 LE/fed and 14350 LE/fed respectively by increasing ratio 6.25%, 8.31% and 9.4% compared to traditional irrigation. On the other hand, the results showed that the total revenue of the wheat crop with 100% water applied compared with 80% water applied under all treatments of traditional and developed for (diesel, electric and solar energies) increased by 3542 to 3960 LE/fed. Generally, the total revenue of developed irrigation system with solar energy were higher than other treatments which was 18310.6 LE/fed.

Net return per feddan (LE/fed)

Data in the Table (10) showed that the net return of the wheat crop (by using diesel energy) with 100% water applied was 8300.4 LE/fed under a traditional irrigation system compared with using diesel, electric and solar energy under developed irrigation system which were 9348 LE/fed, 9652 LE/fed and 10120.6 LE/fed respectively, by increasing ratio 12.62%, 16.28% and 22% compared to traditional irrigation. The total revenue (by using diesel energy) with 80% water applied was 4840 LE/fed under traditional irrigation systems compared with using diesel, electric, and solar energy under a developed irrigation system which was 5673 LE/fed, 5822.6 LE/fed and 6160 LE/fed respectively, by increasing ratio 17.21%, 20.30% and 27.27 % compared to traditional irrigation.

On the other hand, the net return for developed irrigation systems with solar energy was higher than treatments of 10120.6 LE/fed. Generally, data showed that the total revenue of the wheat crop with 100% and 80% water applied under all treatments of developed irrigation systems (diesel, electric, and solar energy) increased compared with treatments of traditional irrigation systems.

Unit profitability (LE)

The results in Table (10) showed that the unit profitability of the wheat crop with 100% water applied has increased from about 408.5 LE for traditional irrigation system with diesel energy to about 434.8 LE, 438.7 LE and 453.2 LE for developed irrigation systems with diesel, electric, and solar energy respectively, by increasing ratio of 6.44%, 7.4% and 11% respectively, compared to traditional irrigation, and the same trend for 80% water applied which has increased from about 302.5 LE of traditional irrigation systems with diesel energy to about 333.7 LE, 336 LE, and 352 LE under developed irrigation system with diesel, electric and solar energy respectively, by increasing ratio 10.31%, 11.1% and 16.36% respectively, compared to traditional irrigation.

Generally, the unit profitability was greater (100% water applied) under a developed irrigation system with solar energy (453.2 LE).

Return on the invested pound (LE)

Data in Table (10) showed that the return on the invested pound with 100% water applied has increased from 0.99 LE under traditional irrigation system with diesel energy to 1.13 LE, 1.15 LE and 1.24 LE under developed irrigation system with diesel, electric and solar energy respectively, by increasing ratio 14.14%, 16.16% and 25.25% respectively, compared to traditional irrigation, and the same trend for 80% water applied which has increased from 0.58 LE under traditional irrigation system with diesel energy to 0.69 LE, 0.69 LE and 0.75 LE under developed irrigation system with diesel, electric and solar energy respectively, by increasing ratio 19%, 19% and 29.3% respectively, compared to traditional irrigation. Generally, the return on the invested pound was greater (100% water applied) under a developed irrigation system with solar energy (1.24 LE).

Table 10. The productive and economic efficiency of the wheat crop under all treatments.

Treatments	A_{100}	A_{80}	B_{100}	B_{80}	C_{100}	C_{80}	D_{100}	D_{80}
Water applied (m^3/fed)	2465	1972	1560	1248	1560	1248	1560	1248
Yield (kg/fed)	3048	2400	3225	2550	3300	2600	3350	2625
Yield (Erdab/fed)	20.32	16	21.5	17	22	17.33	22.33	17.5
Farm price (LE/Erdab)	820	820	820	820	820	820	820	820
Farm price (LE/Ton)	5466.7	5466.7	5466.7	5466.7	5466.7	5466.7	5466.7	5466.7
Total variable costs.	8362	8280	8282	8267	8388	8388	8190	8190
Total revenue (LE/fed.)	16662.4	13120	17630	13940	18040	14210.6	18310.6	14350
Net return (LE/fed.)	8300.4	4840	9348	5673	9652	5822.6	10120.6	6160
Unit profitability (LE/Erdab)	408.5	302.5	434.8	333.7	438.7	336.0	453.2	352.0
Return on the invested pound	0.99	0.58	1.13	0.69	1.15	0.69	1.24	0.75
Rate of return on variable costs	199.3	158.5	212.9	168.6	215.1	169.4	223.6	175.2
Return on water unit	6.76	6.65	11.30	11.17	11.56	11.39	11.74	11.50

Rate of return on variable costs (%)

Data in Table (10) showed that the return on the invested pound with 100% water applied has increased from 199.3 % under traditional irrigation system with diesel energy to 212.9 %, 215.1 % and 223.6 % under developed irrigation system with diesel, electric and solar energy respectively, by increasing 13.6%, 15.8% and 24.3% % respectively, compared to traditional irrigation, and the same trend for 80% water applied has increased from about 158.5 % under traditional irrigation systems with diesel energy to about 168.6 %, 169.4 %, and 175.2 % under a developed irrigation system with diesel, electric, and solar energy respectively, by increasing 10.1%, 11 %, and 16.7% respectively, compared to traditional irrigation. Generally, the return on the invested pound was greater (100% water applied) under a developed irrigation system with solar energy (223.6 %).

Return on water unit (LE/m^3)

The results in Table (10) showed that the return on water unit with 100% water applied has increased from 6.76 LE/m^3 under traditional irrigation system with diesel energy to 11.3 LE/m^3, 11.56 LE/m^3 and 11.74 LE/m^3 under developed irrigation system with diesel, electric and solar energy respectively, by increasing ratio 67.15%, 71% and 73.66 % respectively, compared to traditional irrigation, and the same trend for 80% water applied has increased from about 6.65 LE/m3 under traditional irrigation system with diesel energy to 11.17 LE/m3, 11.39 LE/m3 and 11.74 LE/m3 under a developed irrigation system with diesel, electric, and solar energy respectively, by increasing ratio 68%, 71.27% and 76.54% respectively, compared to traditional irrigation. Generally, the return on water units was higher at 100% water applied for the developed irrigation systems with solar energy (11.74 LE/m^3).

CONCLUSION

Developed irrigation system in old lands, especially in the delta, and the use of renewable energy sources leads to higher economic gains and improved irrigation practices in terms of timing and quantity of irrigation and energy savings in light of current and future global conditions. Therefore, it is more appropriate to raise the efficiency of the irrigation operating system for crops and raise water unit outputs under field conditions Egyptian with the lowest energy consumption, as this study has shown that the amount of water used to irrigate the wheat crop using developed irrigation system decreased by 36.7% compared to traditional irrigation. Moreover, the use of 80% of irrigation requirement with developed irrigation system (reducing the amount of water applied to the wheat crop) leads to reduction of productivity at 80% under developed irrigation system with all types of energy used to irrigation pump.

The use of solar energy in the operating of irrigation pump, lead to the Stability of energy and the flow rate of water from the solar-pump, thereby increasing the operational efficiency of these pumps and thereby increasing the efficiency of water distribution and wheat productivity. On the one hand, irregularity of the flow rate of water from diesel pumps or cut of electricity from electricity pumps leads to decrease operational efficiency and consequently decrease of water distribution efficiency and decrease of wheat productivity.

Recommendation

Motivating farmers and investors and increasing the awareness role light of the increased economic efficiency and crop productivity to cultivate new lands with modern irrigation methods using renewable energy (solar energy) as an alternative to traditional irrigation methods and diesel or electricity energy because of its many advantages, such as clean, inexpensive energy and available during season to save irrigation water.

REFERENCES

Abd El- Rasool, S. F., Tawodros, H.W., Miseha, W.H., and Mahrous, F. N., (1971). Effect of irrigation and fertilization on water use efficiency by wheat "Conf., Ain Shams Univ. Egypt.

Abioye, A.E., Abidin, M.S.Z., Mahmud, M.S.A., Buy amin, S., Mohammed, O.O., Otuoze, A. O., 2023, Model based predictive control strategy for water saving drip irrigation, Encyclopedia of Smart Agriculture Technology, 4, Elsevier B.V., 100179, https:// doi.org/ 10.1016 /j.atech. 2023.100179. Available from.

Awwad, A. H., Mohammed A.S.H., and Shabana, M.M.A., (2016). Evaluation of water management and requirements under developed surface irrigation system. J. Soil Sci. and Agric. Eng. Mansura Univ. Vol. 7(11):847-855, 2016.

Campbell, D.J., (1994). Determination and use of bulk density in relation to soil compaction. In Soane and Ouwerk (Eds). Soil compaction in crop production. Elsever, London and Amsterdam.

Fernandez, J., 2017 ´Plant-based methods for irrigation scheduling of woody crops, Horticulturae 3 35. Available from, http://www.mdpi.com/2311-7524/3/ 2/35.

Garcia, G., (1978). "Soil water Engineering Laboratory Manual". Colorado State Univ. Dept. of Agric. and Chemical Engineering. Fortcollins, Colorado.

Giriappa, S., (1983).Water use efficiency in agriculture .Oxford and IBH publishing C.O. New Delhi.

Jackson, M.L. (1967): Soil chemical analysis. Prentice Hall, Englewood Cliffs, 227–261.

Joshua Wanyama, A., Paul Soddo, B., Prossie Nakawuka, A., Peter Tumutegyereize, A., Erion Bwambale, A., Isaac Oluk , B., William Mutumba, B., Allan John Komakech, A, 2023 Development of a solar powered smart irrigation control system Kit smart agricultural technology volume 5 October.

Klute, A., and Dirksen, C., (1986). Hydraulic conductivity and diffusivity: Laboratory methods. P. 687-734 methods of soil analysis. Part 1 Agronomy 2nd edition. ASA and SSSA, Madison, WI. In A. Klute (ed).

Kumar, J., Mahata,M., Rawat,S., 2018 Frequently Asked Questions on Solar Powered Irrigation Pumps, Deutsche Gesellschaft für International Zu sammenarbeit (GIZ) GmbH, New Delhi, India.

Lozoya, C., Mendoza, C., Mejía, L., Quintana, J., Mendoza, G., Bustillos, M., 2014 Model predictive control for closed-loop irrigation, IFAC Proc. Vol. 19, 4429-34.

Michael Jensen, C., (1978) Some Anomalous Evidence Regarding Market Efficiency, Journal of Financial Economics, Vol. 6, Nos. 2/3 pp 95-101.

Mustafa, F., Mohammed, A., Mohammed, A., Qasim, B., Vladimir, I., Velkin, B., 2023 Stand-alone transformer-less multilevel inverter fed by solar energy for irrigation purposes materials Today: Proceedings 80 1071–1078.

Pardo, M., Manzano, J., Valdes-Abellan, J., Cobacho, R., 2019. Standalone direct pumping photovoltaic system or energy storage in batteries for supplying irrigation networks. Cost analysis. Sci. Total Environ. 673, 821–830. https://doi.org/10.1016/ j. scitotenv.2019.04.050.

Qianwen-Zhang, B., Maosheng Ge, A,B., Pute Wu, B., Fuqiang Wei, B., Shaopeng Xue, B., Bo Wang, B., Xinbo Ge, ,2023. Solar photovoltaic coupled with compressed air energy storage: A novel method for energy saving and high quality sprinkler irrigation Agricultural Water Management Volume 288, 1 October 108496.

Richards, L. A., (Ed.) 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Agriculture Handbook 60, Washington D. C. Water Resources Management, 14: 229–246.

Saad Eddin, M. R., M. Y. El-Ansary, M. A. Awaad and A. S. H. Mohammed 2016. Evaluation of integrated surface irrigation management in the old lands. J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 7(7): 509 – 515.

Tamer, K., Alia, S., Shaymaa, E., Monera, S., 2019. Rehabilitation of Mauritanian oasis using an optimal photovoltaic based irrigation system. Energy Convers. Manag. 199, 111984 https://doi.org/10.1016/j. enconman.2019.111984

Zhang, Y.Q., Ge, M.S., Zhang, Q.W., Xue, S.P., Wei, F.Q., Sun, H., 2023. What did irrigation modernization in China bring to the evolution of water-energy-greenhouse gas emissions? Agric. Water Manag. 282, 108283 https://doi.org/10.1016/j. agwat.2023.108283.

تأثير الري الناقص تحت نظامي الري المطور والتقليدي باستخدام الطاقة الشمسية على التكلفة والإنتاجية في التربة الطينية

أحمد صلاح حسن[1] ، أمين حسين عواد[1] و محمود عبد الحي شبانة [2]

[1]معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – وزارة الزراعة .
[2]معهد بحوث الأراضي والمياه والبيئة – مركز البحوث الزراعية – وزارة الزراعة.

الملخص

تم إجراء هذا البحث خلال موسم الزراعة 2022-2021 بمزرعة خاصة بمحافظة كفر الشيخ بمناطق المشروع لتقييم أثر استخدام مصدر طاقة متجددة (الطاقة الشمسية) للري السطحي المطور في الأراضي القديمة من خلال مقارنته باستخدام مصادر طاقة غير متجددة (الكهرباء والديزل) لنفس نظام الري المطور ونظام الري التقليدي لتحقيق التنمية الزراعية المستدامة بالاضافة الي تأثير الري الناقص على النباتات لتحسين إنتاجية المحاصيل وترشيد مياه الري مما يؤدي إلى تحسين البيئة الزراعية. حيث اعتمد البحث على تقييم اقتصادي مثل التكاليف الكلية للري والطاقة والزراعة وإنتاجية وحدة مياه الري للمحاصيل الشتوية (القمح) وقد اعتمد البحث على تجميع البيانات من خلال المشروع القومي لتطوير الري لزراعة محصول القمح بمحافظة كفر الشيخ.ويمكن تلخيص أهم النتائج التي تم التوصل اليها على النحو التالي:- استخدام الطاقة الشمسية مع نظام الري المطور أفضل من استخدام الطاقة الكهربائية والديزل بالإضافة إلى كونها طاقة نظيفة لا تلوث البيئة، وغير مكلفة ومتوفرة.- يمكن الاستفادة من الري الناقص بنسبة 80% من الري الكامل كما يمكن التغاضي عن انخفاض الإنتاجية والتكاليف مقابل التوفير في المياه.- انخفاض كمية المياه اللازمة لري الفدان الذي يعتمد على طريقة الري المطور بنسبة تبلغ حوالي 36.71% مقارنة بالفدان الذي يروي بطريقة الري التقليدية.- كان العائد على وحدة المياه وإجمالي الإيرادات وصافي العائد أكبر في ظل نظام الري المتطور بالطاقة الشمسية (100% من المياه المضافة) حيث بلغ 11.74 جنيه/م^3، 18310.6 جنيه/فدان و10120.6 جنيه/فدان على التواليالضافة الي الوفر في كمية المياه الارض كنتيجة لاستخدام الري المطور.

الكلمات الدالة: الري المطور-التقليدي - طاقة الكهرباء – الشمسية