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Theoretical analysis of different solar water pumping irrigation systems for seasonal crops in three geographical locations in Egypt

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Abstract

Solar energy has a good potential in several agriculture applications especially in rural and isolated areas and can be considered as a clean substitution fuel instead of fossil fuels. The photovoltaic water pumping system is one of the best alternative irrigation methods. This article presents a procedure for estimating the appropriate size of a photovoltaic system designed to power a pumping system for four irrigation methods (surface, sprinkler, drip, and developed surface irrigation) under different climate conditions for summer of three crops (cotton, thin corn, and soybean) and for winter of three crops (wheat, Bean and Barley). The solar simulation model estimated the hydraulic power, photovoltaic (PV) peak power, PV required area, total system costs and specific water demand according to the type of crop under different irrigation methods in three different geographical locations in Egypt at a different total dynamic head 50,100, and 200 m. As a comparison between the required water demand in several irrigation systems, it is found that the percentage of the amount of water demand per Fadden (m^3/F) related to surface irrigation system for summer crops such as cotton crop was 85.7%, 79.9%, 66.7% in developed surface, sprinkler, and drip irrigation respectively. While in case of thin corn crop was 74.3%, 79.9%, 66.7% and for Soybean was 85.7%, 79.9%, 66.6%, respectively. In winter crops, the percentage of the amount of water demand per Fadden (m^3/F) related to surface irrigation system for wheat crop was 85.6%, 79.9%, 66.7% and for bean crop was 85.7%, 0.79%, 66.7% and for Barley crop was 85.7%, 79.9%, 66.6% in developed surface, sprinkler, and drip irrigation respectively.

Keywords: Solar water pumping system, PV sizing, Cost analysis, Irrigation methods, Beni-Suef.

1. Introduction

Water in several countries around the world is facing a scarce resource due to water contaminations, insufficient flow in some of the rivers and an increase in water demand due to increasing in population and installing new rural and urban areas [1]. Global population growth and land use changes due to agricultural land expansion have intensified the need for world-wide fresh water. Due to global warming, climate change is becoming more impacting both potential fresh water supply and the decline the amount of rainfall [2]. Egypt has a high renewable energy potential including solar, wind and biomass power [3]. While Egypt's farming area stretches from 3.3265 km^2 or 7.91 million Fadden in 2003 (3.3 percent) to 3.7503 km^2 or 8.92 million Fadden in 2012. It still needs to expand its farming areas to meet the growth of its population [4]. Solar power is the world's most plentiful energy source. It is not only a solution to the current energy crisis; it is also an environmentally friendly source of energy. The generation of photovoltaic (PV) is an effective solution to solar energy use. Solar panels are now widely used for street lighting, communications and meet household electric loads. Solar panel costs have been steadily decreasing which encourages its use in different sectors. One of its important applications is the solar water pumping systems. Solar powered irrigation system is considered an effective solution for farmers in the current energy crisis. People used a variety of power sources including animal power, hydropower, wind, solar and diesel fuels [5]. Solar water pumping system (SWPS) is currently considered as an essential and vital solution to solve the current gap between water requirements in the agriculture sector. SWPS can be a cost-efficient and stand-alone solution to meet remote watering needs. The national specialized boards provided a

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comprehensive information for the availability of underground water in the Egyptian desert [6]. There have been many research efforts to reduce irrigation water losses. Drip irrigation is the manner in which the lowest water losses occur and thus the lowest amount of water is required to water a plant adequately [7]. The common methods of irrigation in Egypt are surface, sprinkler, drip irrigation and developed surface irrigation as following [8]:

a) Surface irrigation

It is the most common method that does not require significant cost, as it is characterized by being easy to use by submerging the soil with water

b) Sprinkler irrigation

Sprinkler irrigation is a simulation of the process of rainfall on the ground and is one of the modern irrigation systems that are used to irrigate the desert areas with sandy land, which cannot keep the water for long time and it is also suitable in irrigation of the lands that irrigate the lifting of wells as it is also used in clay lands. It can be easily controlled in the amount and timing of irrigation water

c) Drip irrigation

Drip irrigation is done by making suitable methods that can deliver water to plants and those methods delivered water solely in the forms of points, either as continuous or separate, by using drops. Also, it works to make the irrigation process highly organized.

d) Developed Surface irrigation

is considered the advanced surface irrigation that controlled of water transported by pipes from the source. It has developed techniques and methods

The advantage of using solar energy to power agricultural water pump systems is that increased livestock and irrigation water requirements tend to coincide with the seasonal increase in solar incoming energy. That means, the volume of water pumped by the SWPS at a certain time depends on the total amount of solar energy available during that period. The SWPS's main components are the PV array and its supporting construction, the electric controller and the pump [9]. Solar pumps are classified as an either positive displacement pumps or centrifugal pumps (e.g., diaphragms, pistons or helical motor pumps). The scope of this paper is to present a mathematical model to evaluate the system performance of the SWPS for irrigation of different crops under different TDH. Finally, a complete sizing of the system components is identified; the system cost, power, and land requirements are estimated. Raturi [10] presented a comparison of use of water pumping system by diesel engines and solar power with a feasibility analysis in a rural solar water pumping system. The results of the production tests showed that the cost of the water was EUR 0.65 per m^3 on the basis of the financial simulation values. The estimated pumping costs for solar energy rural areas are 30 percent lower than those for diesel systems. Zainutdinova and Lutpullaev [11] presented the potential of solar energy and the prospect of socioeconomic growth in remote and mountainous areas. The market for solar pumps in Egypt depends very much on the solar radiation and the quantity of subterranean waters contained. The national standard showed the availability of surface water in the Egyptian desert in the following areas: Sinai, East Delta, Middle Delta, West Delta, Middle Egypt, Upper Egypt, Al-Wadi El-Gadid. Cuadros et al. [12] presented an approach to design in Spain, a method based on the assessments of irrigated water requirement (IWR) for photovoltaic water pumping (PVWP) systems for drip irrigation of the olive tree. Hamidat et al. [13] developed a program to test the efficiency of PVWP irrigation systems in the Sahara regions. The study found that PVWP systems are appropriate for small-scale irrigation of crops. Zvonimir and Jure [14] presented a new optimization of PVWP irrigation systems has been proposed. The goal was to reduce the size of PVWP system in light of IWR and water quality limitations different irrigation water pumping systems, in particular (PVWP) versus Diesel Irrigation Water Pumping System (DIWPS) and Wind Power Water Pump (WPWP) systems. The working of PVWP is separate from fossil fuels and thus overcomes all of the associated difficulties: supply of fuel, fluctuating fuel costs, fuel and oil pollution, emissions of exhaust gas and greenhouse gases. Gad [15] added the PV system-driven water pumping technology to a South Sinai, Egypt through computer simulation software. The program calculates the system's hourly performance under different PV array guidelines on every day of the year. Kathiriya et al .[16] illustrated the performance evaluation of rain pipe irrigation under solar photovoltaic pump and found the average water horse power of solar photovoltaic pump ranged from 2.05 to 2.40 hp, 1.84 to 2.16 hp and 1.68 to 1.97 hp at operating pressure of 0.25, 0.50 and 0.75 kg/cm2 during 10:00 am to 4:00 pm also showed that the uniformity coefficient, distribution uniformity and mean application rate is increased as increased the operating pressure and the coefficient of variation is increased as decreased the pressure. Xie et al. [17] presented the Costs of Groundwater-Fed Irrigation in Sub-Saharan Africa Under Two Energy Solutions of Solar or Diesel. Also, compared economic performance of groundwater pumping for irrigation under two energy solutions of solar photovoltaic (PV) and diesel fuel and estimated the life-cycle costs of the power units of two pumping systems for a range of crop and irrigation method.The program calculates the system's hourly performance under different PV array guidelines on every day of the year. Egypt is divided into three main agro-climatic zones: (i) Lower Egypt (Nile Delta) which extends from northern Cairo through to the Mediterranean Sea and has some winter precipitation; (ii) Middle Egypt which runs from south Cairo to the borders of Asyut and is characterized by limited rainfall, and (iii) upper Egypt which run from Asyut to Aswan also, the desert run from south Sinai to Red Sea as shown in Fig.1[18].

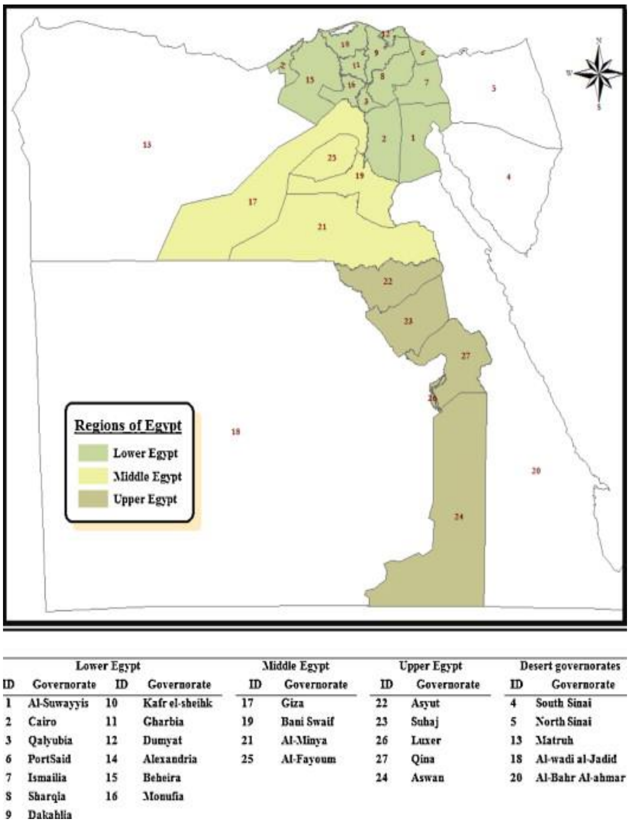
The Geographical data for Beni-Suef in Egypt has coordinate longitude (31.1086578°) and latitude (29.0419507°), Alexandria has longitude (29.9°) and latitude (31.20°), and Aswan has longitude (32.78°) and latitude (23.97°).

2. Mathematical modelling

Some basic steps should be taken in consideration to describe the complete design process of the SWPS:

a. Estimated the amount of solar energy falling on the horizontal surface [19].
b. Water requirements calculation.
c. Calculating the Total Dynamic Head (TDH)
d. Select a pump to cover the water demand and the desired pressure.
e. Sizing of PV capacity (kW)
f. Evaluation of system land needs.
g. Costs SWPS estimate.

Flowchart simulation software is built on the basis of system components mathematical modelling as shown in the flowchart in Fig. 2. This program contains the necessary input data and all the design results are generated by the excess production. The program is versatile and can provide a variety of solutions that meet input data and customer demands and can be used by feeding the specific location information to get similar results at any place around the world.



Lower Egypt				Middle Egypt		Upper Egypt		Desert governorates	
ID	Governorate	ID	Governorate	ID	Governorate	ID	Governorate	ID	Governorate
1	Al-Suwayyis	10	Kafr el-sheihk	17	Giza	22	Asyut	4	South Sinai
2	Cairo	11	Gharbia	19	Bani Swaif	23	Suhaj	5	North Sinai
3	Qalyubia	12	Dumyat	21	Al-Minya	26	Luxer	13	Matruh
6	PortSaid	14	Alexandria	25	Al-Fayoum	27	Qina	18	Al-wadi al-Jadid
7	Ismailia	15	Beheira			24	Aswan	20	Al-Bahr Al-ahmar
8	Sharqia	16	Monufia						
9	Dakahlia								

Fig.1. Main agro-climatic zones of Egypt.

2.1 Calculation of the water demand

Calculating of the water demand based on different methods of irrigation for different crops per Fadden in Beni-Suef city is the average water consumption for many crops per Fadden (Q_{Ac}) m^3/day that provided from Agriculture Research Centre, Water Mining and Field Irrigation Research Department [20].

2.2 Calculating the total dynamic head (TDH)

TDH is the sum of the overall static head (h_s), losses in friction head (h_f) and minor head losses (h_m). The total static head is the difference in height between the source of water input (Z_1) and the outlet level (Z_2). The friction head losses (h_f) are caused by the wall shear stress on the interface between the tubular fluid and the pipe walls. It is directly proportional to the pipe length (L) and inversely proportional to the inner diameter of the pipe (d).

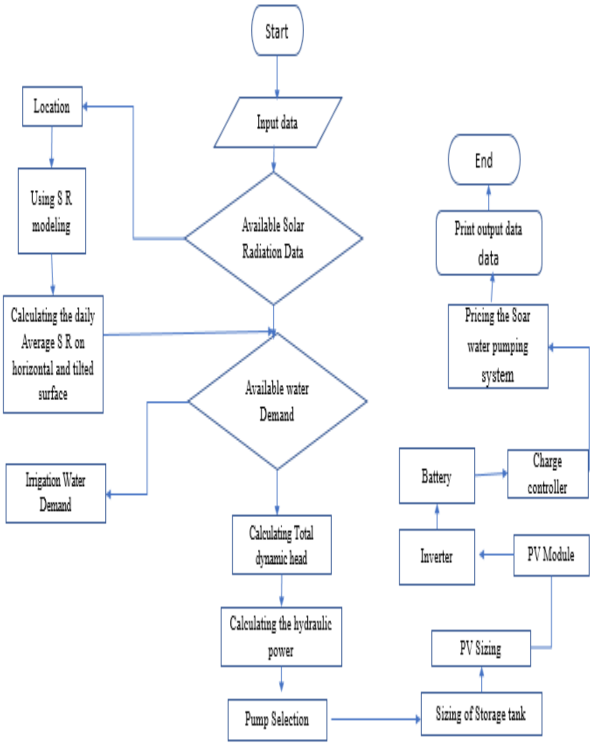


Fig.2. Flow chart of the simulation model.

Additionally, the friction head losses are related to a friction factor (*f*), which is dependent on the Reynolds number (*Re*) of the flow and the relative roughness of the inner pipe walls (ε). The minor head losses (h_m) in the system are due to the unstable turbulent flow in pipe fittings, connectors and valves. Its magnitude is quantified by a loss factor (*k*), which is specific to each type of fitting and independent of the fitting material [21]. The total dynamic pumping head is represented as [22, 23].

$$\text{TDH} = h_s + h_f + h_m = (z_2 - z_1) + \frac{v^2}{2g}\left(f\frac{L}{d} + \Sigma\, k\right) \qquad (1)$$

where v is the velocity of flow (m/s), f is the friction factor, L is the length of pipe (m), d is the pipe diameter (m) and k is the loss coefficient for different components.

2.3 *Pump Selection*

Pump sizing can be calculated focused on these factors [24]:

- Pump flow rate m^3/day
- Pumping head (m).
- Type of operation (centrifugal or positive displacement)
- Water source (surface or submersible).

2.4 *Hydraulic power*

The hydraulic power, P_h required to lift a volume of water over a total head, TDH

$$P_h = \rho g Q \text{TDH} \qquad (2)$$

Where ρ is the density of water (1000 kg/m^3), g is the gravitation (9.8 m/s^2) and Q is the volume flow rate (m^3/s).

2.5 *Estimating the System Land Requirements*

The area of the PV can be calculated from [25,26]:

$$A_{pv} = \frac{E_L}{\eta_{pv}\, \eta_{inv}\, T_c\, H} \qquad (3)$$

where A_{pv} is the photovoltaic module area, m^2, E_L is the required electrical energy for pumps, Wh/d, η_{inv} is the inverter efficiency, η_{pv} is the PV efficiency, H is the daily solar radiation, Wh/m^2 day, and T_c is the temperature coefficient of panel.

2.6 *Sizing the PV capacity (kW)*

The power of PV can be calculated from [24].

$$P_{pv} = A_{pv} H_{sc}\, \eta_{pv} \qquad (4)$$

where H_{sc} is the standard solar radiation 1000 W/m^2

2.7 *Cost calculation of SWPS*

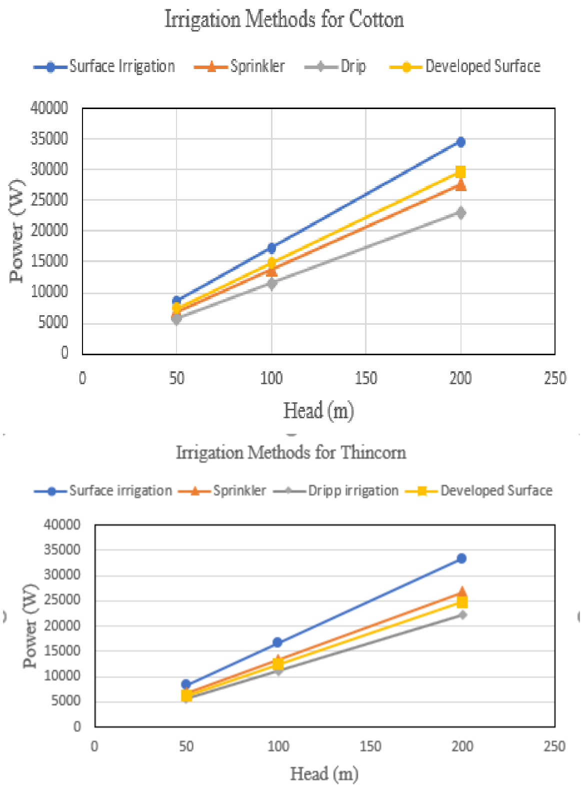
In the current simulation program, the overall cost of the solar water pumping system is estimated taking into account the direct unit price of each of the system components, such as photovoltaic panels, frames, inverters, pumps, pipes and cable systems.

3. Results and Discussion

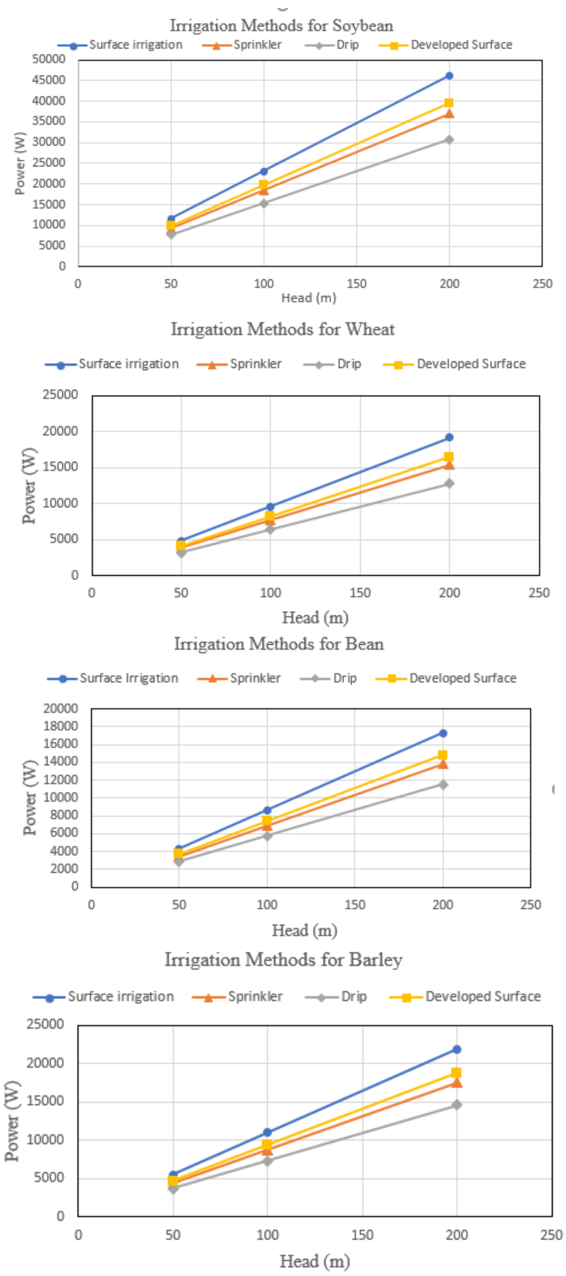
Results illustrated several simulations runs for data of different crops: in Cotton, Thin corn and Soybean in summer and Wheat, Bean and Barley in winter by different irrigation methods: Surface, Sprinkler, Drip and Developed Surface irrigation at different head 50,100 and 200 m, at specific water demand that based on the type of crop. Figures 3-8 illustrate a sample of 3 crops in each season in Beni-Suef city. Figure 3 illustrates the relation between hydraulic power and head of different crops under different irrigation methods. According to the amount of water needed for each crop at different TDH, the power required for pumps (kW) for different summer crops are between (5 to 50 kW) and for winter crops are (2 to 24 kW) and may be increased depending on values of TDH. It was found that the lowest pumping power was in case of drip, sprinkler, developed surface and flooded (surface) irrigation system for cotton, wheat, bean, soybean and barley respectively. While in case of the thin corn crop, it is found that the pump power in sprinkler irrigation method is higher than that in surface developed irrigation method that refers to the amount of water needed for this crop.

Figure 4 illustrates the water demand per Fadden for comparison between summer, winter crops. It is clear from the figure that the surface irrigation method has higher water consumption than other methods and on the other hand, thin corn crop in case of sprinkler irrigation has higher amount of water than the developed surface and drip irrigation methods because that type of corn needs higher amount of water in case Sprinkler than developed surface irrigation.

The comparison showed that developed surface irrigation method is better than surface irrigation method to provide amount of water. The calculated data showed the amount of water required ranges in case surface irrigation in summer crops from (380.9 to 509.25 m^3/day) and in winter crops was from (211.5 to 241 m^3/day) but in developed surface irrigation method in summer crops is from (326.5 to 436.5 m^3/day) and in winter crops was from (181.25 to 206.625 m^3/day) also, Summer crops required amount of water in case of sprinkler irrigation from (304.7 to 407.3 m^3/day) and drip irrigation from (253.9 to 339.5 m^3/day) and winter crops required amount of water in sprinkler irrigation method from (169.166 to 192.75 m^3/day) and in drip method from (141 to160.6 m^3/day) as shown in Fig.4.


Irrigation Methods for Cotton

Irrigation Methods for Thincorn


Irrigation Methods for Soybean

Irrigation Methods for Wheat

Irrigation Methods for Bean

Irrigation Methods for Barley

Fig.3. Relation between pump power and head of different irrigation systems in Beni-Suef city.

Figures 5-8 showed electric energy consumed (kWh), exact areas of PV panels (m^2), power of PV (kW), and total costs at different heads for different crops in two seasons; summer and winter respectively. The electric energy consumed can be calculated as given in Table 1. The energy consumed at different TDH is illustrated in Fig.5 for different crops.

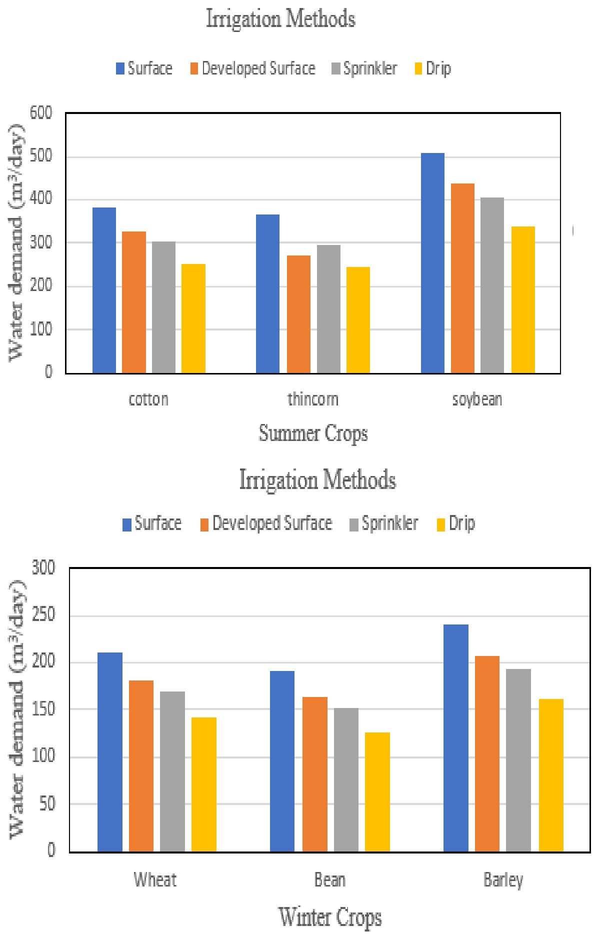


Fig.4. Water demand for different crops (m^3/day) in Beni-Suef city.

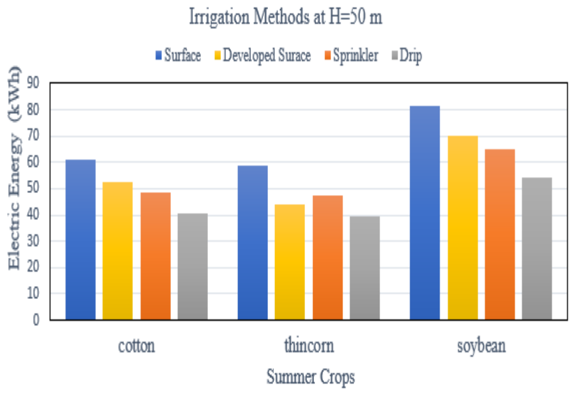


Fig.5.a Electric energy consumed (kWh) at head = 50 m in Beni-Suef city for different crops

Table 1. Calculated required electric energy consumed (kWh) at different TDH for many crops under four irrigation methods in Beni-Suef city.

Summer Crops	Surface irrigation	Developed surface irrigation	Sprinkler irrigation	Drip irrigation
Summer crop	TDH=50 m			
cotton	60.998	52.283	48.794	40.662
Thin Corn	58.912	43.780	47.126	39.280
Soybean	81.547	69.897	65.233	54.364
	TDH=100 m			
cotton	121.997	104.566	97.588	81.324
Thin Corn	117.824	87.559	94.253	78.560
Soybean	163.093	139.794	130.467	108.729
	TDH=200 m			
cotton	243.993	209.131	195.176	162.647
Thin Corn	235.648	175.119	188.506	157.120
Soybean	326.186	279.588	260.933	217.458
Winter Crops	TDH=50 m			
Wheat	33.868	29.024	27.089	22.578
Bean	30.492	26.141	24.393	20.323
Barley	38.592	33.087	30.865	25.721
	TDH=100 m			
Wheat	67.736	58.047	54.178	45.157
Bean	60.983	52.283	48.786	40.646
Barley	77.183	66.174	61.730	51.442
	TDH=200 m			
Wheat	135.471	116.095	108.355	90.314
Bean	121.966	104.565	97.573	81.293
Barley	154.366	132.348	123.461	102.884

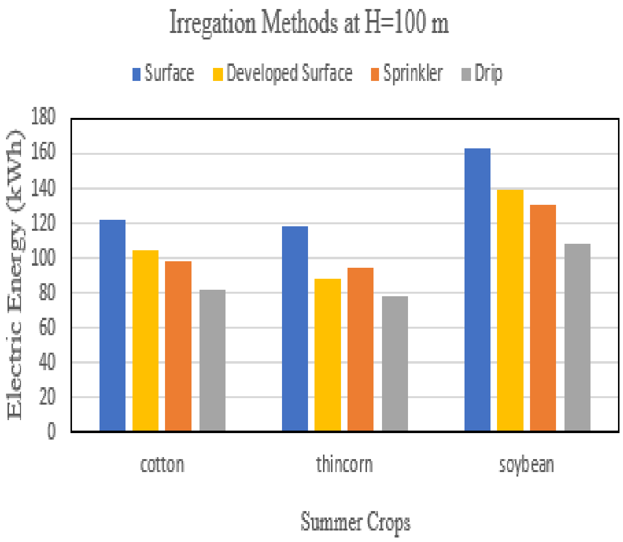


Fig.5.b Electric energy consumed (kWh) at head = 100 m in Beni-Suef city for different crops

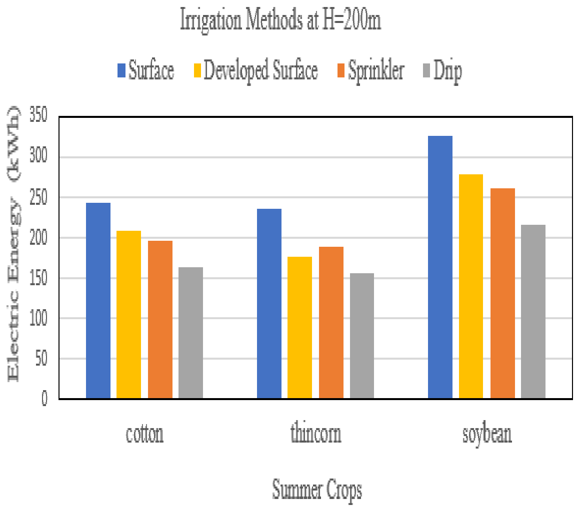


Fig.5.c Electric energy consumed (kWh) at head = 200 m in Beni-Suef city for different crops

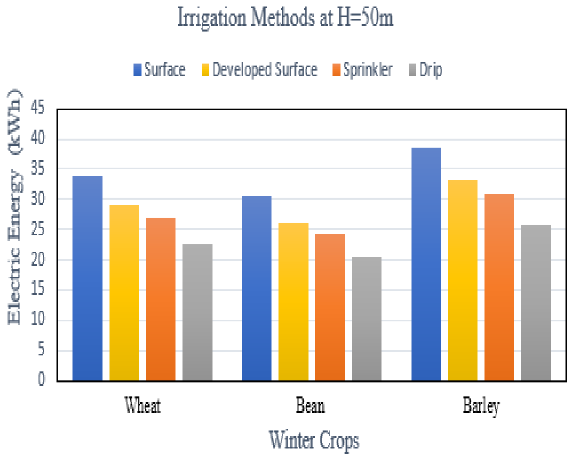


Fig.5.d Electric energy consumed (kWh) at head = 50 m in Beni-Suef city for different crops

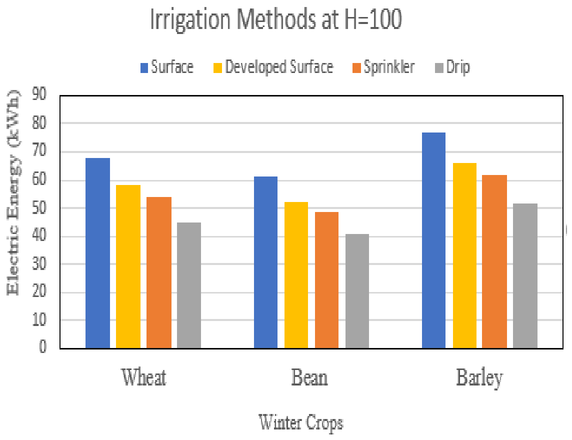


Fig.5.e Electric energy consumed (kWh) at head = 100 m in Beni-Suef city for different crops

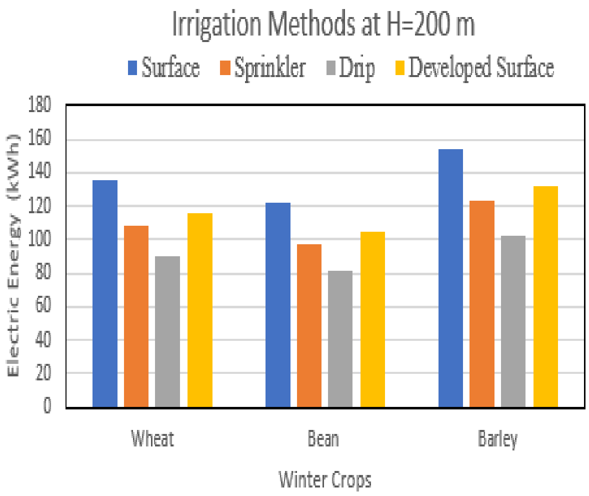


Fig.5.f Electric energy consumed (kWh) at head = 200 m in Beni-Suef city for different crops

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The total actual area of photovoltaic (m^2) at different TDH and the variation of PV peak power and it is related area for different crops under four irrigation methods in Beni-suef city at different TDH is shown in Figs.6 and 7.

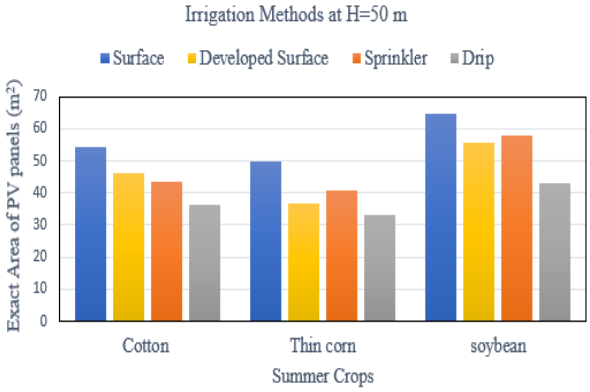

Fig.6.a Exact area of panels, m^2 of different crops in Beni-Suef city at Head = 50 m

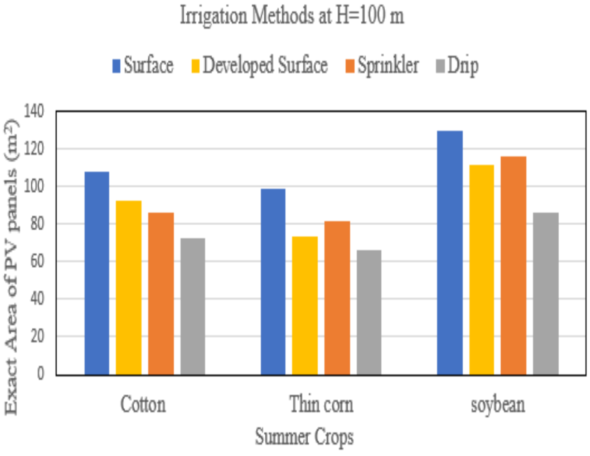

Fig.6.b Exact area of panels, m^2 of different crops in Beni-Suef city at Head = 100 m

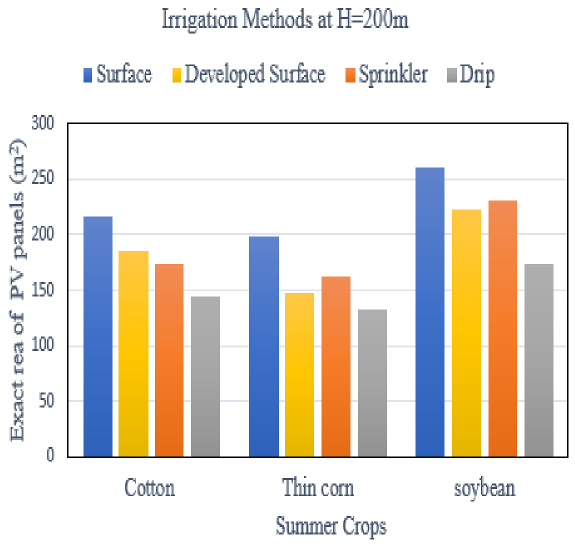

Fig.6.c Exact area of panels, m^2 of different crops in Beni-Suef city at Head = 200 m

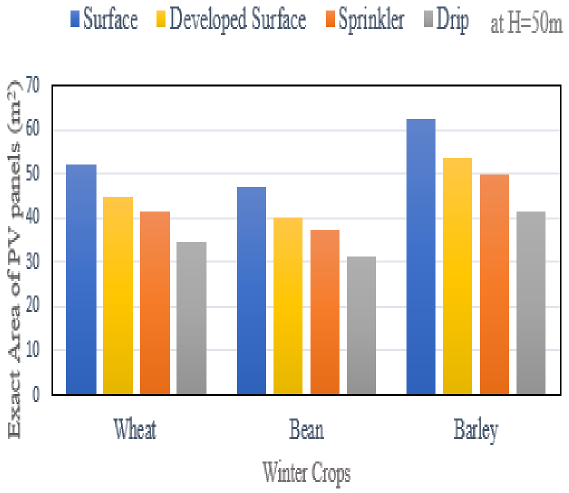

Fig.6.d Exact area of panels, m^2 of different crops in Beni-Suef city at Head = 50 m

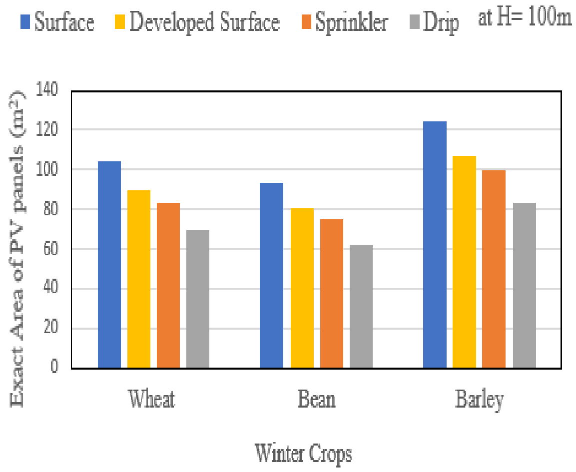

Fig.6.e Exact area of panels, m^2 of different crops in Beni-Suef city at Head = 100 m

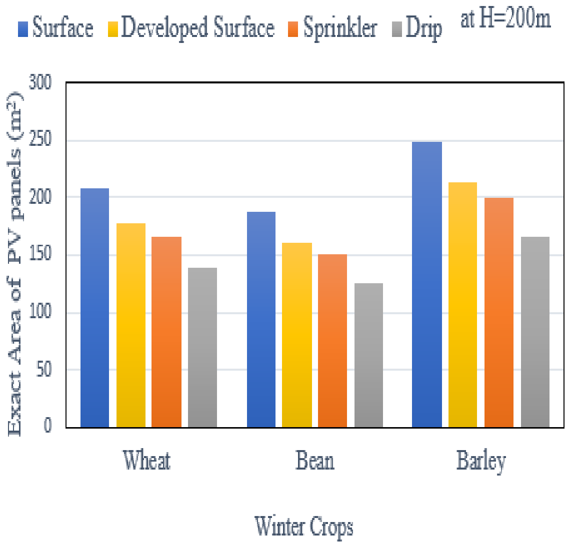

Fig.6.f Exact area of panels, m^2 of different crops in Beni-Suef city at Head = 200 m

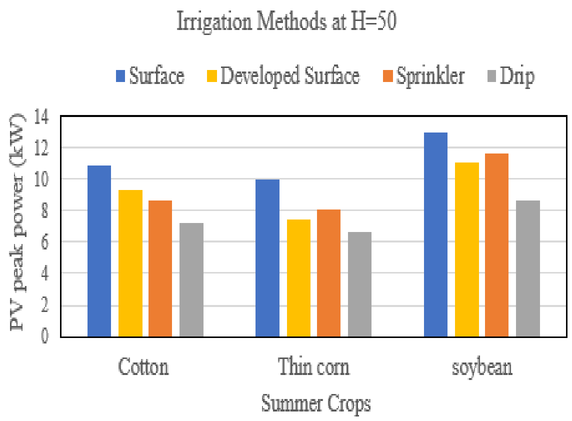

Fig.7.a PV peak power variation of different crops at head=50 m in Beni-Suef city.

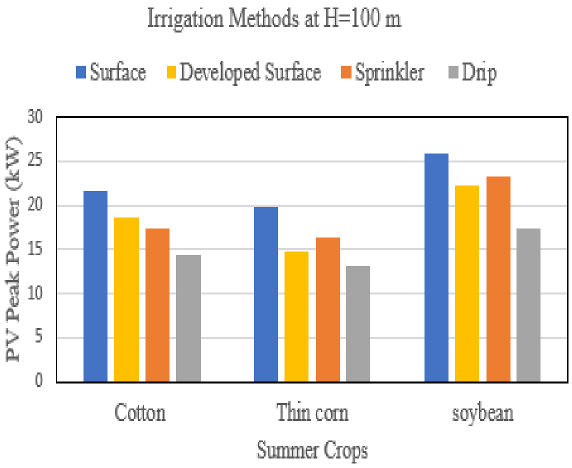

Fig.7.b PV peak power variation of different crops at head=100 m in Beni-Suef city.

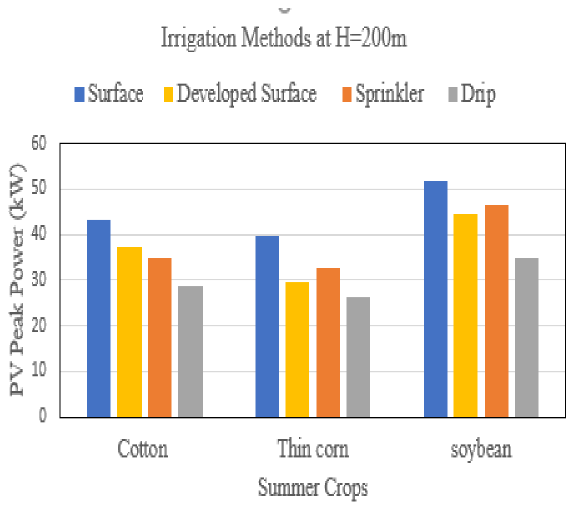

Fig.7.c PV peak power variation of different crops at head=200 m in Beni-Suef city.

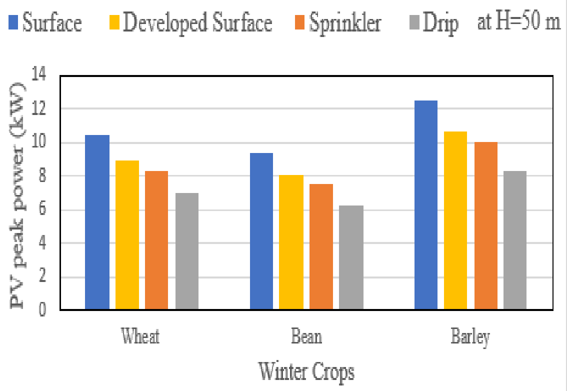

Fig.7.d PV peak power variation of different crops at head=50 m in Beni-Suef city.

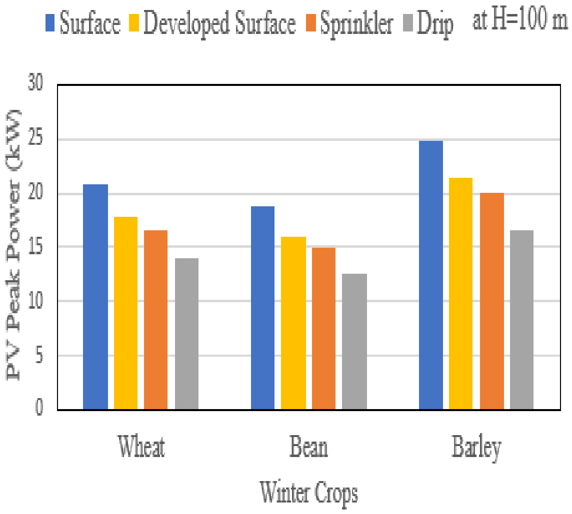

Fig.7.e PV peak power variation of different crops at head=100 m in Beni-Suef city.

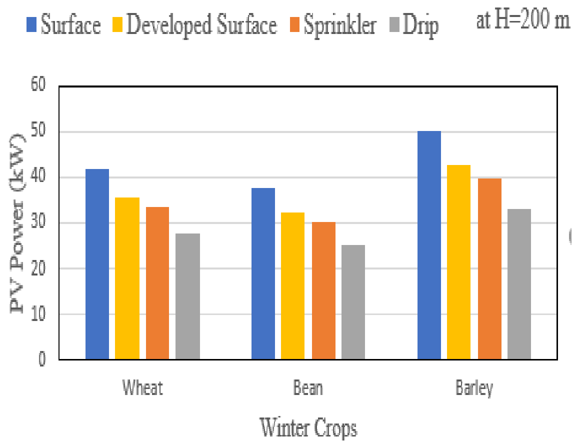

Fig.7.f PV peak power variation of different crops at head=200 m in Beni-Suef city.

The system cost depends on several parameters, for instance manufacturing country, company, brand name (for the main components like PV panel, pumps, and inverters), PV type of technology as mono crystalline or polycrystalline silicon, thin film, etc. Fig.8 illustrates total cost of different crops at different heads.

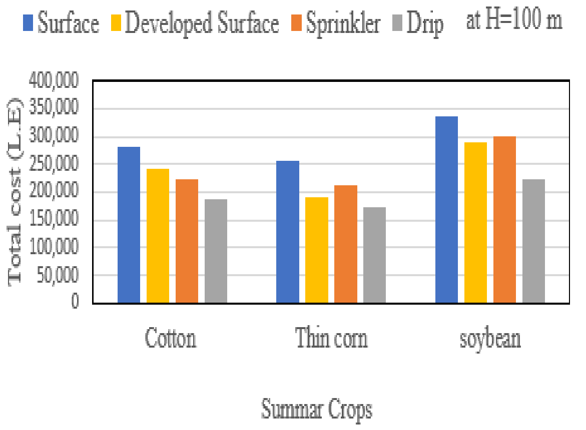

Fig.8.a Total costs of different crops at head = 100 m in Beni-Suef city.

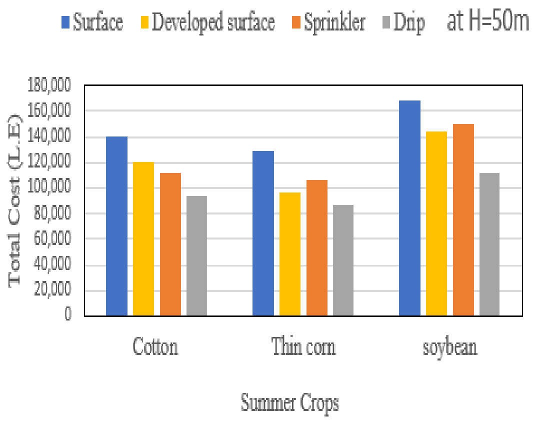

Fig.8.b Total costs of different crops at head = 50 m in Beni-Suef city

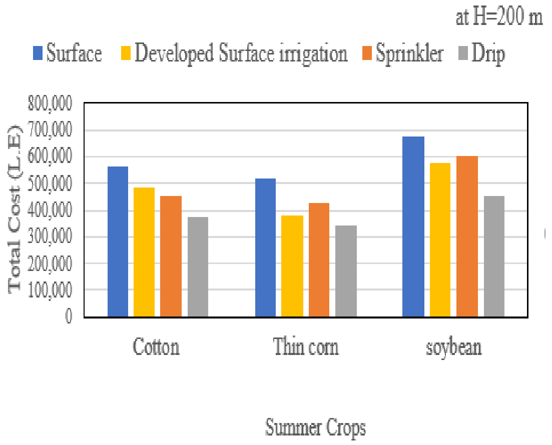

Fig.8.c Total costs of different crops at head = 200 m in Beni-Suef city

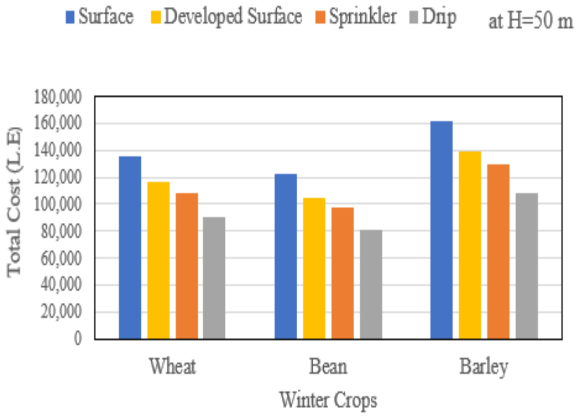

Fig.8.d Total costs of different crops at head = 50 m in Beni-Suef city

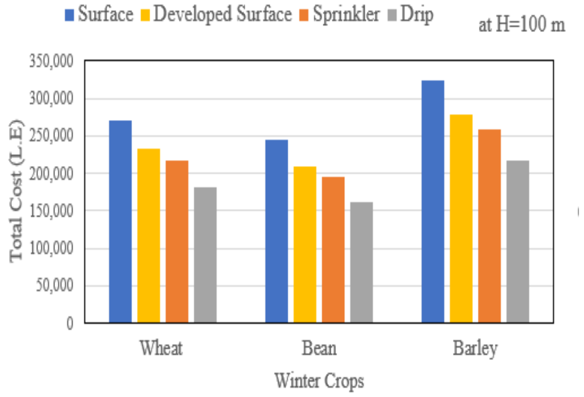

Fig.8.e Total costs of different crops at head = 100 m in Beni-Suef city

Figures (9&10) illustrate the relation between head and hydraulic power at different crops in summer and winter for different irrigation methods in Alexandria and Aswan respectively. According to the amount of water needed for each crop in Alexandria and Aswan at different TDH, the power required for pumps (kW) for the following summer crops are between (5 to 45 kW) and for winter crops are (2 to 22 kW) in Alexandria and in Aswan the power required for pumps (kW) in summer crops are (5 to 60 kW) and for winter crops are (5 to 30 kW). The values of pump power are increased depending on the values of TDH as shown in Figs. (9&10).

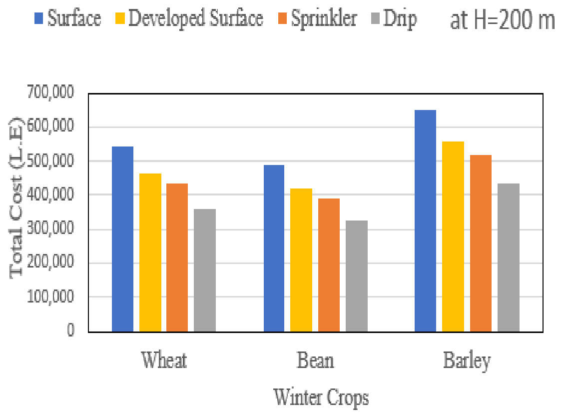

Fig.8.f Total costs of different crops at head = 200 m in Beni-Suef city

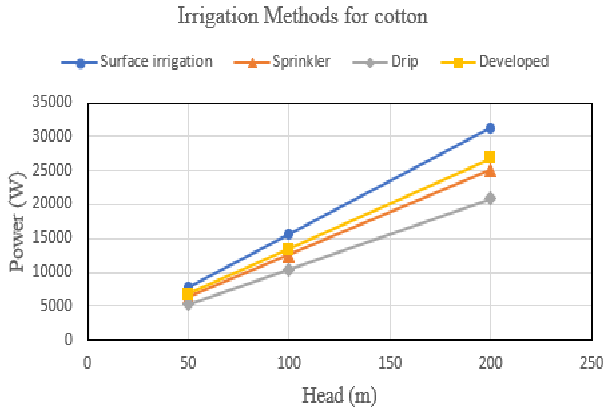

Fig.9.a The relation between pump power and head in Alexandria city

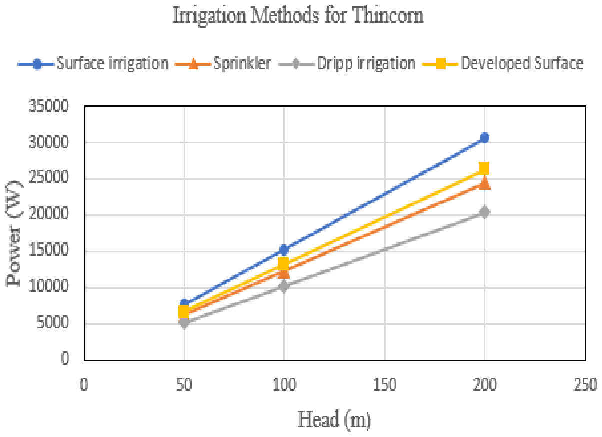

Fig.9.b The relation between pump power and head in Alexandria city

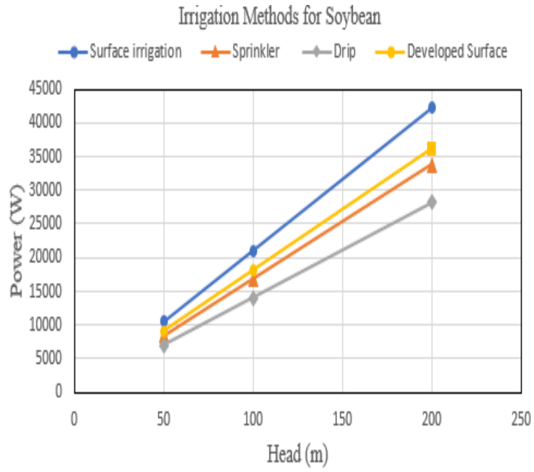

Fig.9.c The relation between pump power and head in Alexandria city

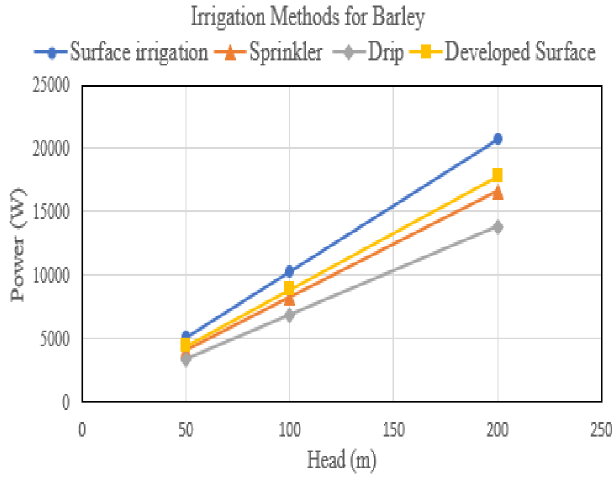

Fig.9.f The relation between pump power and head in Alexandria city

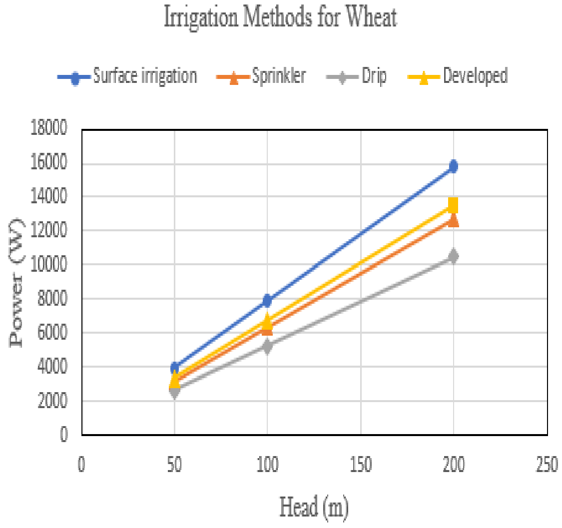

Fig.9.d The relation between pump power and head in Alexandria city

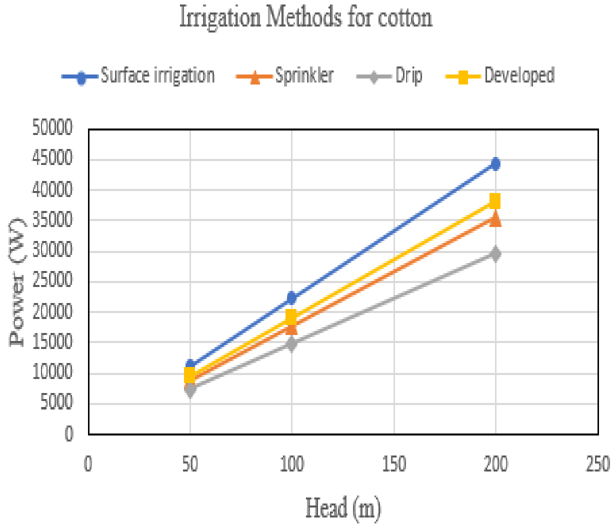

Fig.10.a The relation between pump power and head in Aswan city.

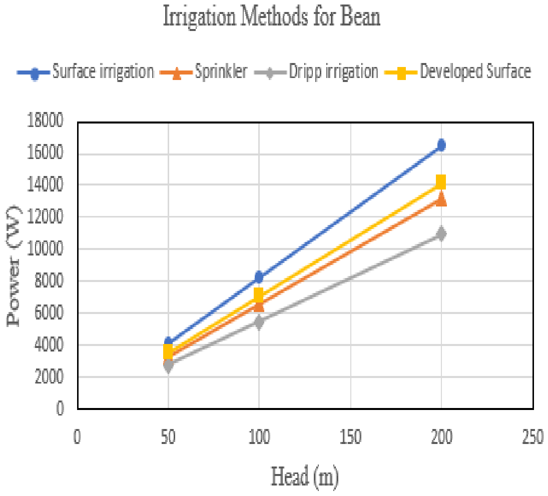

Fig.9.e The relation between pump power and head in Alexandria city

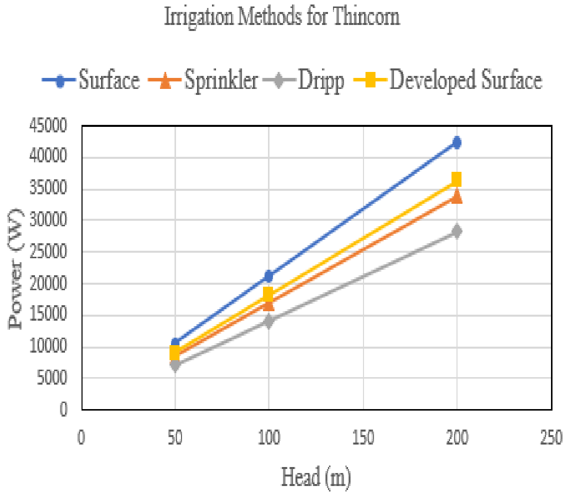

Fig.10.b The relation between pump power and head in Aswan city.

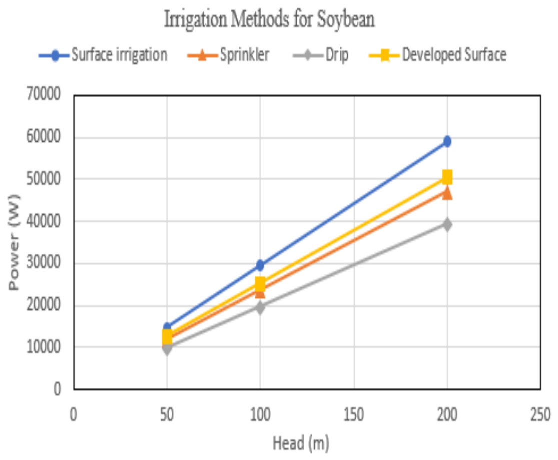

Fig.10.c The relation between pump power and head in Aswan city.

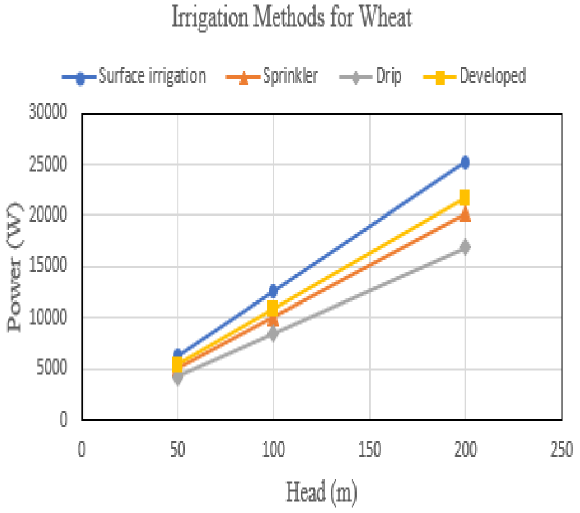

Fig.10.d The relation between pump power and head in Aswan city.

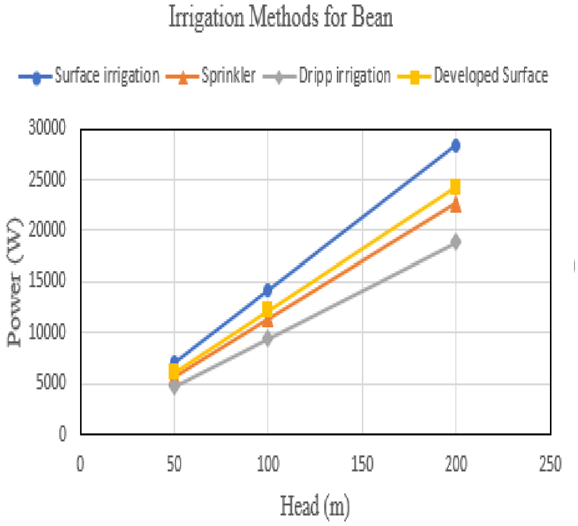

Fig.10.e The relation between pump power and head in Aswan city.

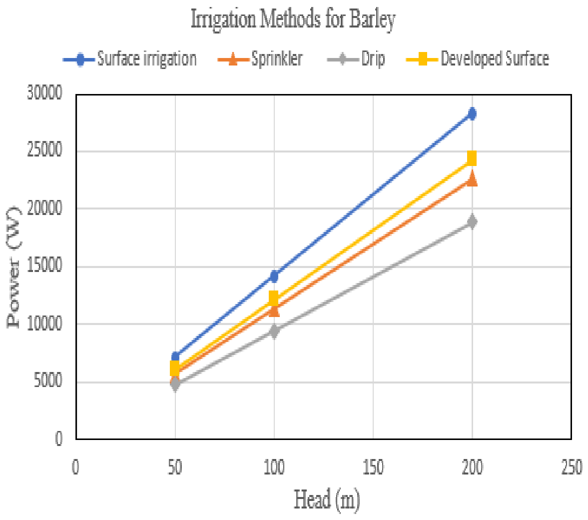

Fig.10.f The relation between pump power and head in Aswan city.

The water demand significantly varied for different crops in different locations like Alexandria, Beni-Suef and Aswan, cities, respectively. Therefore, four different methods of irrigation are used in simulation model with different heads (50,100 and 200 m) as shown in Fig.11. Also, it can be calculated as given in Table 2.

Table 2. Calculated water demand (m^3/day) for some crops in the three cities.

Crops	Surface irrigation	Alexandria	Beni-Suef	Aswan
Cotton		345.4	381	489.5
Thin Corn		337.5	367.9	467.5
Soybean		464.9	509.3	648.8
Crops	Developed Surface irrigation	Alexandria	Beni-Suef	Aswan
Cotton		296	326.5	419.6
Thin Corn		289.3	273.4	400.7
Soybean		398.5	436.5	556
Crops	Sprinkler irrigation	Alexandria	Beni-Suef	Aswan
Cotton		276.3	304.7	391.6
Thin Corn		270	294.3	274
Soybean		371.8	407.3	519
Crops	Drip irrigation	Alexandria	Beni-Suef	Aswan
Cotton		230.2	253.9	326.3
Thin Corn		225	245.3	311.7
Soybean		309.9	339.5	432.5

As comparison between PV peak power (kW) in several irrigation systems at TDH (50,100 and 200 m), the percentage of PV peak power per Fadden at TDH (50 and100 m) respectively related to TDH 200 m for studied summer crops in three cities for different irrigation methods are 25% and 50%. The results from the simulation model are used to compare PV peak power (kW) variation with different crops at previous irrigation methods of the same crops as a sample for the same studied cities, at TDH = 50 m as an example as shown in Fig. 12.

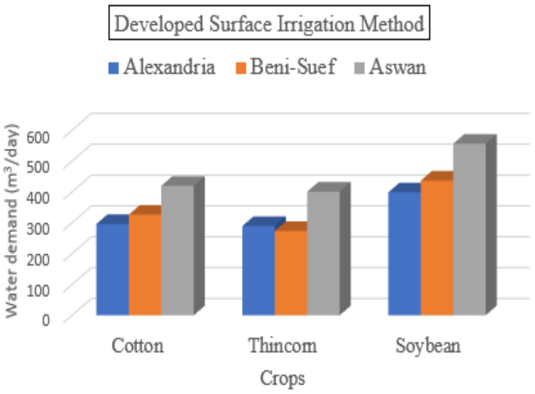

Fig.11.a Comparison between water demands (m^3/day) of crops for different cities under different irrigation methods

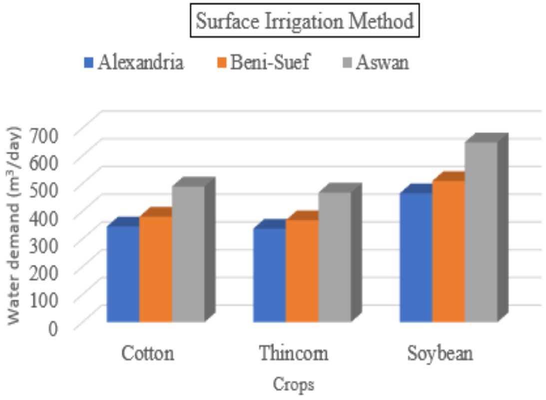

Fig.11.b Comparison between water demands (m^3/day) of crops for different cities under different irrigation methods

Table 3. indicates the exact calculated data of photovoltaic peak power values (kW) with some crops at TDH 50 m per Fadden as sample at three cities under four irrigation methods. Fig.13 illustrates the total cost of the PV panels for different water demand applied loads for the same studied cities, Alexandria, Beni-Suef and Aswan cities, respectively, for TDH = 50 m as example.

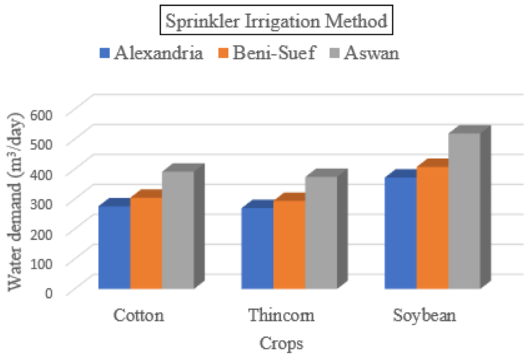

Fig.11.c Comparison between water demands (m^3/day) of crops for different cities under different irrigation methods

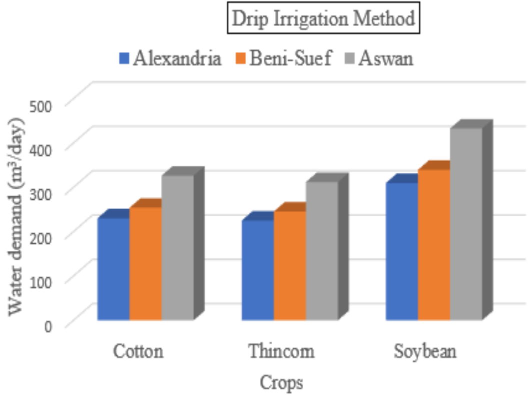

Fig.11.d Comparison between water demands (m^3/day) of crops for different cities under different irrigation methods

Table 3. calculated PV peak power values (kW) with different crops for three cities using different irrigation methods at TDH 50 m.

Crops	Surface irrigation	Alexandria	Beni-Suef	Aswan
Cotton		9.5	10.8	15.3
Thin Corn		8.6	9.9	15.5
Soybean		11.	12.9	16.8
Crops	Developed Surface irrigation	Alexandria	Beni-Suef	Aswan
Cotton		8.2	9.3	13.1
Thin Corn		7.4	7.4	13.4
Soybean		9.7	11.7	14.4
Crops	Sprinkler irrigation	Alexandria	Beni-Suef	Aswan
Cotton		7.6	8.7	12.3
Thin Corn		7.0	8.1	12.5
Soybean		9.1	11.6	13.4
Crops	Drip irrigation	Alexandria	Beni-Suef	Aswan
Cotton		6.3	7.2	10.2
Thin Corn		5.8	6.6	10.4
Soybean		7.8	8.6	13.4

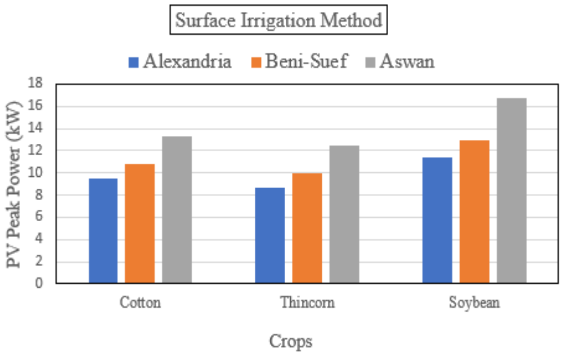

Fig. 12.a Comparison of Solar PV peak power variation of different crops in different cities

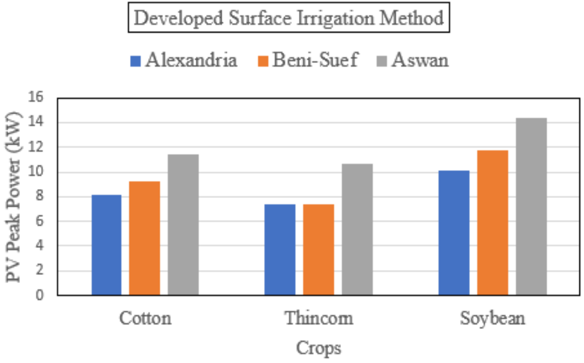

Fig. 12.b Comparison of Solar PV peak power variation of different crops in different cities

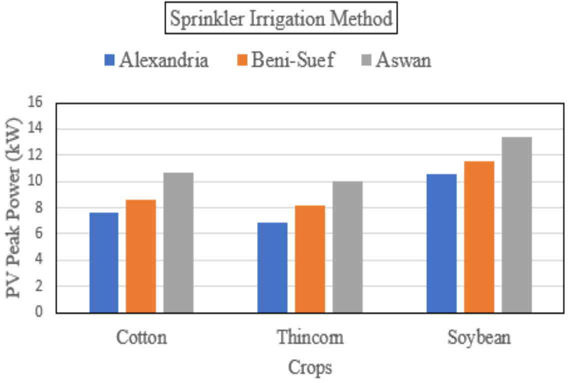

Fig. 12.c Comparison of Solar PV peak power variation of different crops in different cities

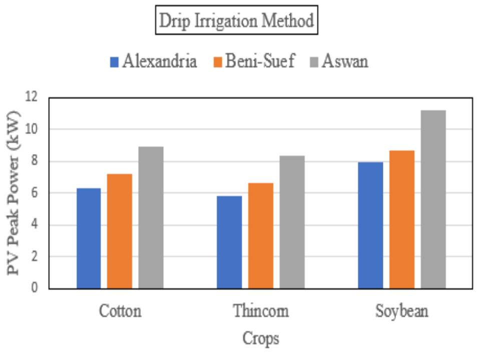

Fig. 12.d Comparison of Solar PV peak power variation of different crops in different cities.

The system cost depends on several parameters, for example manufacturing country/company, brand name (for the main components like PV panel, pumps, and inverters), PV type of technology (for example, mono crystalline or polycrystalline silicon, thin film, …etc.). As in this study for the three cities, several runs of the simulation model were performed to provide the total cost of the solar water pumping system in L.E for different irrigation methods per Fadden at different TDHs. The obtained results are shown in Fig.13.

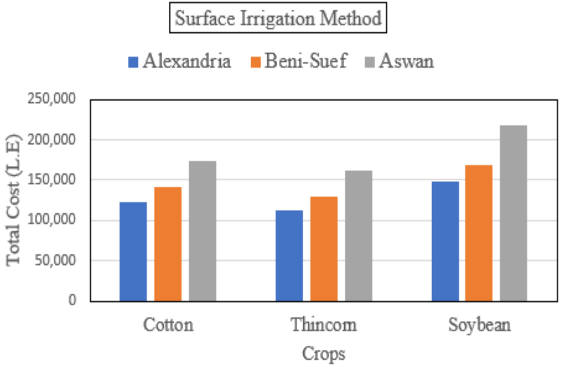

Fig.13.a Comparison between total costs (L.E) of different crops for different cities.

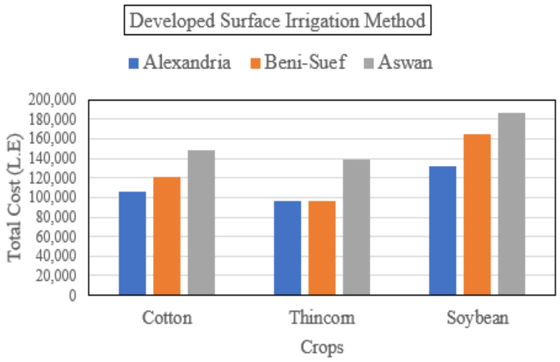

Fig.13.b Comparison between total costs (L.E) of different crops for different cities.

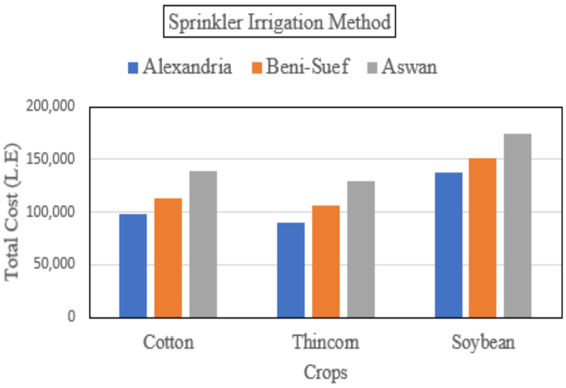

Fig.13.c Comparison between total costs (L.E) of different crops for different cities.

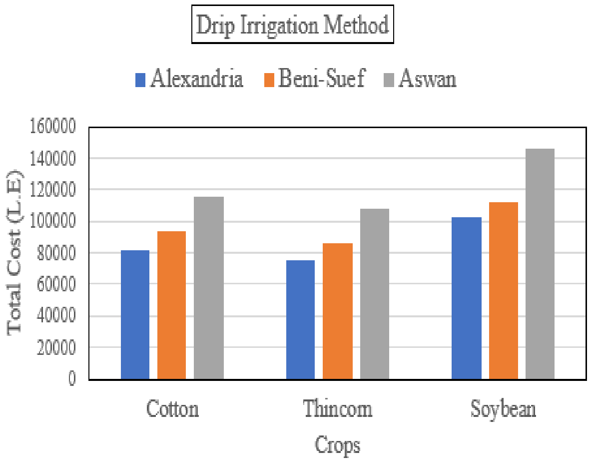

Fig.13.d Comparison between total costs (L.E) of different crops for different cities.

4. Conclusion

Solar water pumping systems are considered to be a feasible solution for many applications in rural and remote areas, especially where traditional sources of electricity are not accessible or available at affordable prices, because of the quick need for sustainability. The present study focused on a study for a complete design of a photovoltaic solar water pumping system for irrigation under different irrigation methods components with different total dynamic head and specific water demand based on the type of crops. This is done by the presently developed computer program. The hydraulic power, PV peak power, PV required area, and total system costs for different total dynamic head ranged from 50,100 and 200 m were calculated in Beni-Suef city and also done a comparison between Beni-Suef, Aswan and Alexandria. The simulated results can give for any head, the corresponding pump electric power at the desired total dynamic head, the required PV peak power and its related area requirements and the corresponding total cost of the system components in L.E. The amount of water demand percentage per Fadden (m^3/F) for summer crops as a cotton crop in case developed surface, sprinkler, drip irrigation respectively, is (86 %, 80 %, 67%). Also, the thin corn crop save amount of water per Fadden under previous irrigation methods is (74%, 79%, 66%) respectively, and Soybean has (85 % ,79.9 %, 66.7 %). In winter crops as Wheat crop provides amount of water percentage per Fadden under surface developed, sprinkler and drip irrigation are (85%, 79%, 66%) also, the Bean crop save amount of water per Fadden under previous irrigation methods respectively, is (85.7%, 80%, 66%) and Barley has (86%, 79.97%, 66%). Due to the hot climate and increasing the rate of evaporation, the number of irrigation periods is increased in Aswan city which consequently increasing its water demand /Fadden which leads to increasing the power of PV system and its cost respectively even it is located in hottest weather than Ben-suef and Alexandria cities. Several simulations were performed through most of Egyptian cities focusing on previous three cities. The present results offered a powerful tool for designers, users as well as costumers and it is found that the PV solar water pumping system is economically feasible and can be used anywhere in the world as long as the data relevant to the site is fed to the program. The result indicated that Beni-suef city has a significant potential for solar water pumping system to provide clean energy sources needed for irrigating the desert area located nearby the governorate to provide sustainable development with a clean environment to the new land reclamation community.

Reference

[1] M.M. Haque, P. Egodawatta, A. Rahman, A. Goonetilleke. "Assessing the significance of climate and community factors on urban water demand." International Journal of Sustainable Built Environment 4-2 (2015) 222-230.

[2] S.A. Woznicki, A.P. Nejadhashemi, and M. Parsinejad. "Climate change and irrigation demand: Uncertainty and adaptation." Journal of Hydrology: Regional Studies 3 (2015) 247-264.

[3] A. Khalil, A. Mubarak, S. Kaseb. "Road map for renewable energy research and development in Egypt." Journal of Advanced Research 1 (2010) 29-38.

[4] M.E. Hereher, "The status of Egypt’s agricultural lands using MODIS Aqua data." The Egyptian Journal of Remote Sensing and Space Science 16 (2013) 83-89.

[5] S. Harishankar, R.S. Kumar, K. P. Sudharsan, U. Vignesh, and T. Viveknath."Solar powered smart irrigation system." Advance in Electronic and Electric Engineering 4-4 (2014) 341-346.

[6] S.M.A. Ibrahim, H.H. El-Ghetany, and A.G.M. Shabak. " Mathematical modeling and performance evaluation for a solar water pumping system in Egypt." Journal of Al-Azhar University Engineering Sector 13-48 (2018) 946-957.

[7] H.M. Darouich, C.M.G. Pedras, J. M. Goncalves, L. S. Pereira. "Drip vs. surface irrigation: A comparison focusing on water saving and economic returns using multi-criteria analysis applied to cotton." Biosystems engineering 122 (2014) 74-90.

[8] D. Dvoskin, K. Nicol, and E.O. Heady. "Irrigation energy requirements in the 17 western states." Agriculture and energy. Academic Press, 1977. 103-112.

[9] A. M. Kishta,"Designing, modeling, and testing a solar water pump for developing countries." , Ph.D thesis, Iowa State University, Dissertations 391, https://lib.dr.iastate.edu/rtd/391 (2002).

[10] A. Raturi, "Feasibility study of a solar water pumping system." Applied Solar Energy 47-1 (2011) 11-13.

[11] Kh. K. Zainutdinova, and S. L. Lutpullaev. "Solar power and the possibility of socio-economic development in the remote and mountainous areas of Uzbekistan." Applied Solar Energy 47-4 (2011) 327-335.

[12] F. Cuadros, F.L.Rodrıguez , A. Marcos, J. Coello. "A procedure to size solar-powered irrigation (photoirrigation) schemes." Solar energy 76 (2004) 465-473.

[13] A. Hamidat, B. Benyoucef, and T. Hartani. "Small-scale irrigation with photovoltaic water pumping system in Sahara regions." Renewable Energy 28 (2003) 1081-1096.

[14] Z. Glasnovic, and J. Margeta. "A model for optimal sizing of photovoltaic irrigation water pumping systems." Solar energy 81 (2007) 904-916.

[15] H.E. Gad. "Performance prediction of a proposed photovoltaic water pumping system at South Sinai, Egypt climate conditions." Thirteenth International Water Technology Conference, IWTC13. 2009

[16] G.R. Kathiriya, G.V. Prajapati, A.M. Paghdal, H.D. Rank and S.V. Kelaiya. "Performance evaluation of rain pipe irrigation under solar photovoltaic pump." The Pharma Innovation Journal 2021; 10(4) (2021) 587-591 .

[17] H. Xie, C. Ringler, and Md. A. H. Mondal. "Solar or Diesel: A Comparison of Costs for Groundwater- fed Irrigation in Sub- Saharan Africa under Two Energy Solutions." Earth's Future (2021) 1-21.

[18] I.K. El-Gafy, A.M. El-Ganzori, and A.I. Mohamed. "Decision support system to maximize economic value of irrigation water at the Egyptian governorates meanwhile reducing the national food gap." Water Science 27 (2013) 1-18.

[19] H.H. El Ghetany, I.T. Zedan. A. Mostafa, and Aya. Gamal "Estimation and validation of a clear sky hourly global solar radiation in Beni-Suef, Egypt." Egyptian Journal of Chemistry (2020) Vol., 63, No. 11 pp. 4483 – 4491

[20] Land, Water and Environment Research Institute, Agriculture Research Center, Water Mining and Field Irrigation Research Department. http://www.arc.sci.eg/, (2018)

[21] Z. Glasnovic, and J. Margeta. "A model for optimal sizing of photovoltaic irrigation water pumping systems." Solar energy 8 (2007) 904-916.

[22] D.H. Muhsen, T. Khatib, and H.T. Haider. "A feasibility and load sensitivity analysis of photovoltaic water pumping system with battery and diesel generator." Energy Conversion and Management 148 (2017) 287-304.

[23] H. Kudela, "Hydraulic losses in pipes”, Wroclaw University of Science and Technology WUT Division of Numerical Flow Modeling

https://www.researchgate.net/publication/265535267_Hydraulic losses in pipes, 2015

[24] A. Allouhi, M. S. Buker, H. El-houari, A. Boharb, M.B. Amine, T. Kousksou, and A. Jamil. "PV water pumping systems for domestic uses in remote areas: Sizing process, simulation and economic evaluation." Renewable Energy 132 (2019) 798-812.

[25] R.J. Chilundo, U.S. Mahanjane, and D. Neves. "Design and performance of photovoltaic water pumping systems: comprehensive review towards a renewable strategy for Mozambique." Journal of Power and Energy Engineering 6-7 (2018) 32-63.

[26] A. Al-Badi, H. Yousef, T. Al Mahmoudi, M. Al-Shammaki, A. Al-Abri, and A. Al-Hinai. "Sizing and modelling of photovoltaic water pumping system." International Journal of Sustainable Energy 37-5 (2018) 415-427.

Nomenclatures

A_{pv}	PV area, m^2
d	Pipe diameter, m
E_L	daily required electrical energy for pumps the Wh/d
f	friction factor
g	Earth gravity, 9.8 m/s^2
H	Daily irradiation, Wh/m^2/d
H_{SC}	Standard solar irradiation, 1,000 W/m^2
hf	Major loss, m
hm	Minor loss, m
hs	Total static head, m
k	The loss coefficient for different component.
l	Pipe length, m
P_h	The hydraulic Power, W
P_{PV}	PV power, W

Q	Total water demand per day, m^3/day
TDH	Total Dynamic Head, m
T_C	Temperature correction factor of the PV module
v	Velocity of flow, m/s
z_1 z_2	Height difference between water source inlet (z_1) and level of water outlet(z_2), m
p	Water density, kg/m^3
η_{inv}	Inverter efficiency
η_{pv}	PV efficiency