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Investigation study of a large- scale solar energy powered groundwater pumping system for irrigation in Najaf city-Iraq

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Abstract
This work presents a study and design of a large-scale solar energy powered groundwater pumping system for irrigation in Najaf city - Iraq. The system is expected to produce sufficient water pumping to cover the specified area. We built two system depended on daily water use for wheat to calculate number of pumps, panels and the power of each panel, the first case study for 28 m ground water depth which needs 16 pumps and each pump need 80W,10 panels and 300 w power for each panel. The other case study for 100 m ground water depth which needs 5 pumps and each pump need 500W, 20 panels and 250w power for each panel. The System is done by using Matlab/Simulink which contains solar arrays; stages DC-DC boost converter, DC shunt motor, and centrifugal pump. In addition, perturbation and observation (P&O) algorithm based maximum power point tracker (MPPT) was used to improve the system efficiency. The results show that the system able to coverage the specified area with sufficient water to irrigate the crops required. And in RETSCREEN after determined our location calculated the Daily water use per unit, Water use reduction, Electricity- daily, Electricity-annual and reduction and the emission of 5.9 tco2 that is equivalent to 13.8 Barrels of crude oil not consumed. The result show that the system able to coverage specific area with sufficient water to irrigate the crop required.

Keywords: PV panel; Irrigation; Water pumping system; Solar photovoltaic.

1. Introduction

Renewable energy source represented by solar cells have become a popular alternative electrical energy source. In the last few years the photovoltaic generation have been increased due to features of solar cell which considered as solution to the local electrical grid crisis in addition to solar source is energy-friendly environment [1]. The use of energy sources to water pumping is a great problem in Iraq. Most of farmer is at far away from local grid lines so provides it with energy and transporting fuel to this rural village is difficult. Hence the use of photovoltaic is a good solution for the water pumping application in farmer irrigation due to solar panels do not need a fuel, maintenance and it cheaper comparison with other sources of energy [2]. There are different researches have been proposed to deploy solar powered water pumping for irrigation System. Abdulhamid Alshamani and Tariq Iqbal [3] research was dynamic modeling by using Matlab / Simulink. This method contains various module such as 11.5 Kw solar

charrays, two stages DC-DC boost converter, 5.5 kW DC shunt motor, and centrifugal pump. System results shown the ability the delivering the required energy with quite satisfactory controller dynamic performance. The results also demonstrate that the output power is changing corresponding with the irradiation and temperature variation without the MPPT and boost converter Also, increasing in temperature directly affects the PV output as it goes down, while decreasing in temperature improves the performance of the PV array. While H. E. Gad [4] study develops the perdition for performance photovoltaic water pumping system in South Sinai, Egypt based on using simulation programs. The results of the perdition were efficiency of photovoltaic module is approximately constant during the operating hours. The predicted values of PV array efficiency range from 13.86% in winter to 13.91% in summer. Korpale et al. [5] studied the performance water pumping system depended on solar energy and conventional electrical energy. The main results of this study were drawn from comparison of solar water pump and conventionally powered water pump: due to solar PV based output the efficiency of solar pump was increased to 39%, motor characteristics are almost equal for PV power source and conventional power source and MPPT controllers are necessary to obtain best efficiency points of solar PV array.
In this paper, we try to study and simulate a water pump energy system solar panels as an alternative for conventional source of electrical energy for irrigation in Najaf city- Iraq. At starting a simple control technique (power electronics device) which is also cost effective has been proposed to track the operating point at which maximum power can be coerced from the PV system under changing environmental conditions. A software simulation model will be developed Matlab/Simulink and the RETSCREEN photovoltaic project model to evaluate the energy production, calculate a cost, number of pumps that required and Calculates environmental pollution from Greenhouse gases (GHG) emission.

2. Methodology
The present work provides a general approach for the design and selection of the suitable technology for irrigation purposes. A standalone solar powered water pumping system is designed with PV modules, DC Water pumps, batteries; stages DC-DC boost converter, maximum power point tracker (MPPT), and the calculation of solar radiation as shows in Figure 1.

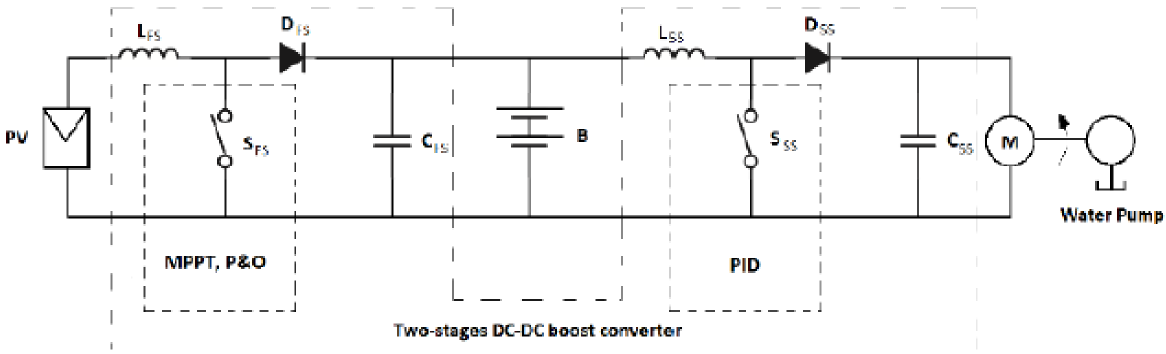

Figure1. The block diagram of the proposed system [3].

2.1 The hardware of the system
2.1.1 Photovoltaic
Photovoltaic (PV) used to convert the radiation energy in the sunlight into electricity, hence a (PV) pumping systems can be used such as complimentary, unlimited, highly useful, economical, efficient, not exhausted source and environmentally clean. Equations (1-7) were used to build module based on the equivalent circuit of solar cell shows below in Figure 2. Matlab / Simulink based model for PV module was built using these equations, as shown in Figure 3.

$$V_t = \frac{K \times T_{op}}{q} \quad (1)$$

$$I_{rs} = \frac{I_{SC}}{e^{\frac{V_{OC} \times q}{K \times C \times T_{op} \times n}}} \quad (2)$$

$$I_{sh} = \frac{V + I_{rs}}{R_p} \quad (3)$$

$$I_d = \left(e^{\frac{V + I_{rs}}{N \times V_t \times C \times N_S}} - 1 \right) \times I_S \times N_p \quad (4)$$

$$I = I_{ph} N_p - I_d - I_{sh} \quad (5)$$

$$V_{oc} = V_t \ln\left(\frac{I_{sh}}{I_s} \right) \quad (6)$$

$$I_{ph} = G_K \left[I_{SC} + K\left(T_{op} - T_{ref}\right)\right] \quad (7)$$

where: V_t: Thermal voltage, K: Boltzmann's constant 1.38e-23, q: Charge of an electron 1.6e-19C, T_{op}: Operating temperature in Celsius, T_{ref}: Reference temperature 25 °C, I_{rs}: Diode reverse saturation current, I_{sc}: Short circuit current, V_{oc}: Open circuit voltage, C: Number of cells in a module, n: Ideality factor, I_{sh}: Shunt current (A), V: Output voltage from the module (V), R_p: Resistor of modules in parallel , I_d: Diode current, N: Diode ideality factor, N_s: Number of modules in series, N_p: Number of modules in parallel, I_s: Diode reverse saturation current (A), I: Output current from the module (A), I_{ph}: Photon current, G_k: Solar irradiance ratio.

2.1.2 Modelling stage DC-DC boost converter

The stage of DC-DC boost converter using to produce output voltage of PV array higher level than a voltage of source to provide the demand of water pump. The stage DC-DC converter gets max power from PV array. MPPT (maximum power point tracker) used to increase the efficiency of PV system.

2.1.3 Modelling of DC motor

In PV water pumping system used DC motor because it can be directly compiled with PV modules and controls a water pump to flow water.

2.1.4 Centrifugal pump

Solar pumps are available in several capacities depending upon the requirement of water and they are connected directly to the solar array using DC power produced by the solar panels. Batteries are used to provide electricity storage to allow pumping in cloudy conditions or at night. The pump specifications are shown in Table 1.

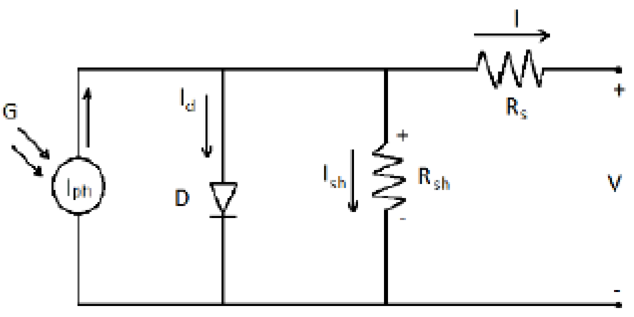

Figure 2. The equivalent circuit of solar cell [3].

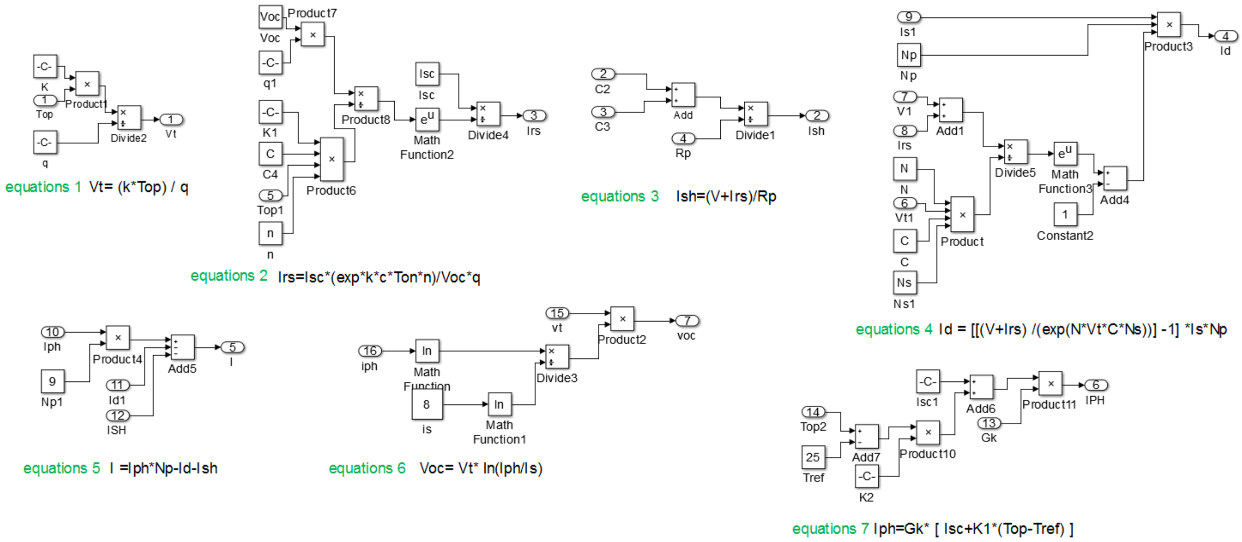

Figure 3. Overview of the solar array modeled in simulink.

Table 1. Pump specification.

Model	Voltage (V)	Pump power (W)	Max flow M3/H	Max head (M)	Outlet(IN)
3DSS0.5-28-12-80	12	80	0.5	28	1*/0.75*
3DSS1.7-109-48-500	48	500	1.7	100	1*/0.75*

2.1.5 The calculation of solar radiation

The calculation of solar radiation is important for design photovoltaic pumping system to knowledge a value of output power from PV modules, and that is performed through determine the location of the required place for supply it by solar power (Figure 4).

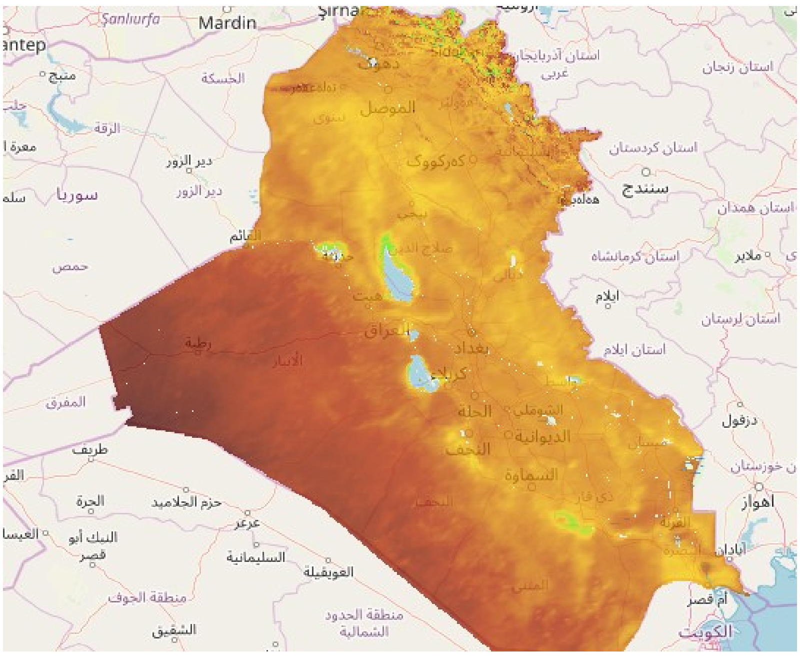

Figure 4. Solar radiation map of Iraq.

3. Result

3.1 In RETSCREEN

The results shown the calculation the daily water use to irrigation some of crops and the electricity daily and annual for two cases for pump at power=80W and head=28m and the other case at power=500W and head= 100m as in Tables 1 and 2. In Tables 3 and 4 the results shown the calculation the number of PV panels that needed for the pumps, and total power for these panels and the solar collector area [6].

Table 2. The weather parameters in Najaf.

Month	Air temp.	Relative humidity	preciptation	Daily solar radiation-horizaontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	Ċ	%	mm	kWh/mƨ/d	kPa	m/s	Ċ	Ċ-d	Ċ-d
Jan.	9.4	54.3%	13.64	2.29	100.9	3.3	9.0	267	0
Feb.	11.8	46.0%	10.64	3.74	100.7	3.5	11.7	174	50
Mar.	16.8	35.4%	8.06	4.93	100.4	3.7	17.2	37	211
Apr.	23.8	27.0%	5.70	5.87	100.1	3.7	24.7	0	414
May	30.1	19.6%	2.17	6.94	99.8	3.9	31.6	0	623
June	34.4	14.4%	0.00	8.13	99.3	4.9	35.9	0	732
Jul.	36.6	14.1%	0.00	7.79	99.0	5.0	37.9	0	825
Aug.	36.3	14.7%	0.31	7.09	99.2	4.3	37.5	0	815
Sep.	32.3	16.6%	0.30	6.01	99.7	3.6	33.0	0	669
Oct.	26.2	24.5%	4.03	4.27	100.3	3.3	26.5	0	502
Nov.	17.2	41.5%	10.80	2.92	100.7	3.2	17.2	24	216
Dec.	11.1	51.8%	7.44	2.49	101.0	3.2	10.7	214	34
Annual	23.9	29.9%	63.09	5.25	100.1	3.8	24.5	715	5092

Table 3. Calculation the crops' water use at power= 80W and head=28 m [6].

Crops	Quantity (ha)	Daily water use per unit (m^3/d/ha)	Water use reduction %	Efficiency of DC pump %	Electricity-daily (kW)	Electricity-annual (kW)
1.Wheat	1	48	85	90	4.1	1485
2.Barley	1	57	85	90	4.8	1764
3.Winter vegetables	1	31	85	90	2.6	959
4.yellow corn	1	116	85	90	9.8	3589
5.Pistachio field	1	46	85	90	3.9	1423
6.Sesame	1	89	85	90	7.5	2754
7.Sunflower	1	110	85	90	9.3	3404
8.The mash	1	105	85	90	8.9	3249
9.Summer vegetables	1	100	85	90	8.5	3094

Table 4. Calculation the crops' water use at power= 500W and head=100m [6].

Crops	Quantity (ha)	Daily water use per unit (m^3/d/ha)	Water use reduction %	Efficiency of DC pump %	Electricity-daily (kW)	Electricity-annual (kW)
1.Wheat	1	48	85	90	14.5	5305
2.Barley	1	57	85	90	17.3	6299
3.Winter vegetables	1	31	85	90	9.4	3426
4.yellow corn	1	116	85	90	35.1	12820
5.Pistachio field	1	46	85	90	13.9	5084
6.Sesame	1	89	85	90	26.9	9836
7.Sunflower	1	110	85	90	33.3	12157
8.The mash	1	105	85	90	31.8	11604
9.Summer vegetables	1	100	85	90	30.3	11051

Table 5. Calculation the PV total power that needed by pump 80W.

The crops	Power capacity for each panels (W)	Number of panels	The total power for PV array (W)	The area that coverage by PV array (m^2)
1.wheat	80	16	1280	11.2
2.barley	80	16	1280	11.2
3.winter vegetables	80	10	800	7
4.yellow corn	80	26	2080	18.2
5.pistachio field	80	15	1200	10.5
6.sesame	80	25	2000	17.5
7.sunflower	80	30	2400	21
8.the cattle	80	35	2800	24.5
9.summer vegetables	80	33	2640	23.1

Table 6. Calculate the PV total power that needed by pump 500W.

The crops	Power capacity for each panels (W)	Number of panels	The total power for PV array (W)	The area that coverage by PV array (m^2)
1.wheat	500	5	2500	15.21
2.barley	500	5	2500	15.21
3.winter vegetables	500	3	1500	9.9
4.yellow corn	500	8	4000	26.3
5.pistachio field	500	5	2500	16.4
6.sesame	500	7	3500	23
7.sunflower	500	9	4500	29.6
8.the cattle	500	12	6000	39.4
9.summer vegetables	500	10	5000	32.9

3.2 In Matlab

The simulation of PV modules are shown in Figure 6. Figure 7 shown the values of current and voltage changed with solar radiation, so the value of output power would change as shown in Figure 8.

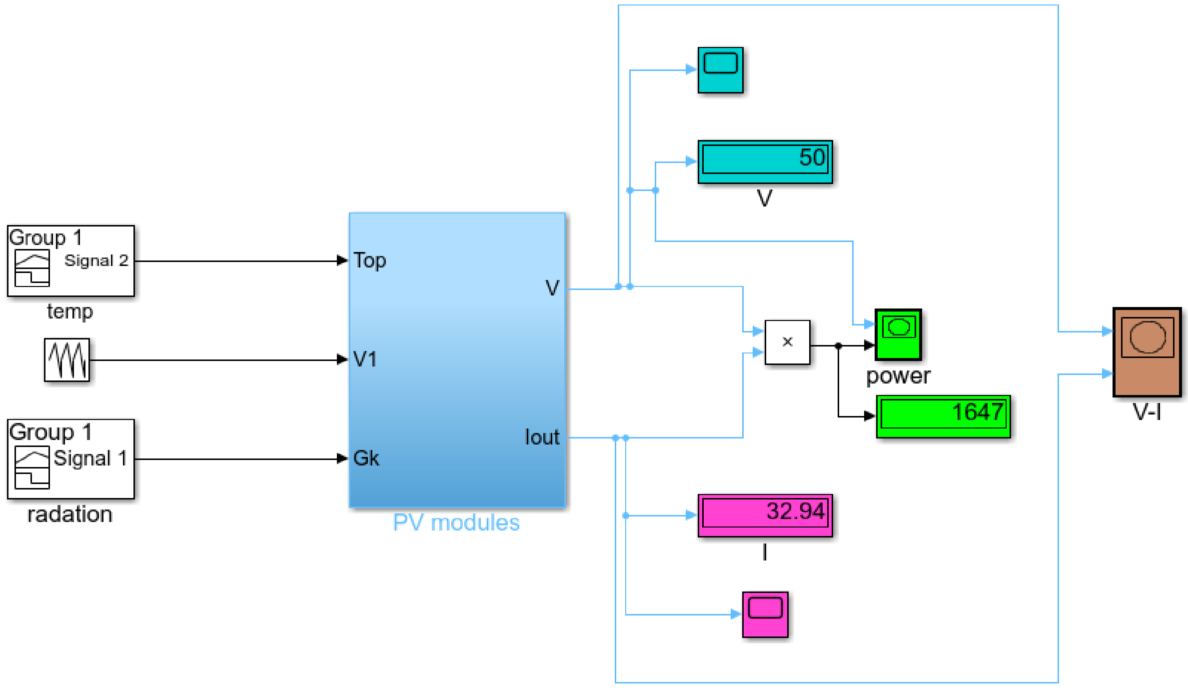

Figure 6. Simulation of PV modules.

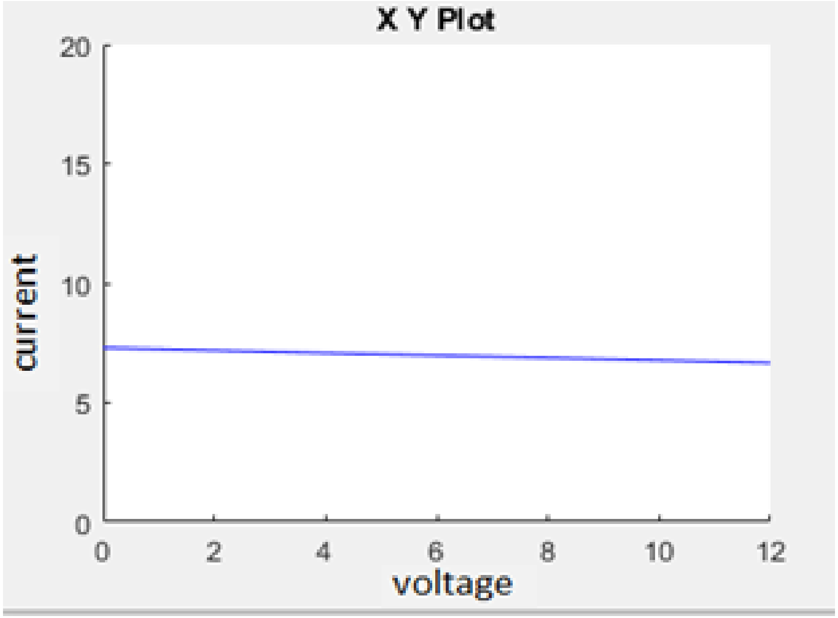

Figure 7. PV output current and voltage.

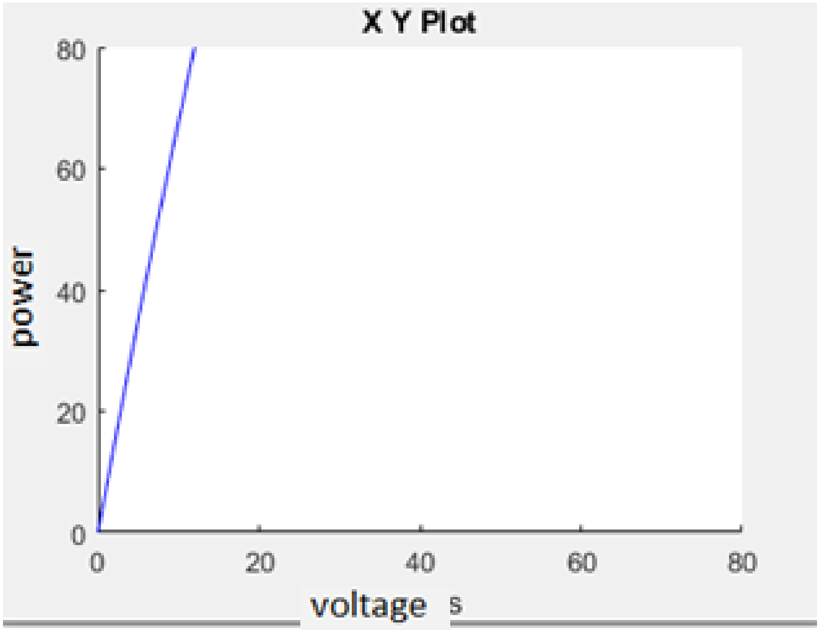

Figure 8. PV output power.

4. Conclusion

Designed simulation a water pump energy system solar panels as an alternative for conventional source of electrical energy for irrigation in Najaf city- Iraq. At starting a simple control technique (power electronics device) which is also cost effective has been proposed to track the operating point at which maximum power can be coerced from the PV system under changing environmental conditions. A software simulation model will be developed Matlab /Simulink and the RETSCREEN photovoltaic project model to evaluate the energy production, calculate a cost, number of pumps that required and Calculates environmental pollution from GHG emission. The results reviewed the simulation of the proposed system in Matlab and the calculation number of solar panels that required to provide energy to pumps and the area of panels in RETSCREEN. And it showed that the system able to coverage specific area with sufficient water to irrigate the crop required.

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