Innovative technology of Egyptian mosques by using solar energy and reusing ablution water in sustainable crop production

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Abstract: Egypt is nowadays facing a lot of challenges, such as limited water and energy resources. In the near future and after building El-NAHDA Dam in Ethiopia, Egypt will suffer from a severe aqueous shortage. Another fatal problem is the unavailability of getting enough energy supplies. Here, the problem of energy is a natural consequence of unsustainable development of energy patterns followed during the last decades. There are many new water resources that have not been well exploited in agriculture. One of these resources is the ablution water in the Egyptian mosques. This new resource can be managed by solar (photovoltaic) energy, as Egypt has good weather with high rates of solar radiation which can reach up to 3000 hours/year. This study carried out to investigate the impact and feasibility of reusing the ablution water as a new source for irrigation and pumping it by photovoltaic (PV) on sustainable crop production. The green roof designs were, traditional design (green roof using fresh water in irrigation and using electric energy for pumping it) and the other design was sustainable design (green roof by reusing ablution water as a new water resource for irrigation and using PV energy for pumping it) and each system has been studied for three cases according to the number of green layers as one, two and three green layers. Statistical analysis indicated that maximum yield of vegetable crops and maximum net income for seasons 2015 and 2016 were occurred under the sustainable design with three green layers.

Keywords: reuse ablution water, solar energy, photovoltaic system, drip irrigation, green roofs, water and energy use efficiency

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1 Introduction

Sustainable development is a necessary condition for continuation of the earth. “Healthy and Comfortable” is a necessary condition for the continuation of life. Additionally, we are facing serious energy and natural resource shortage, where global climate change is the problem which cannot be ignored (Hsieh et al., 2011).

Green building concept has been adopted by many nations as the best way forward in preserving our resources and sustaining our environment (Al-Kaabi et al., 2009). This is about how to minimize environmental degradation caused by building practices and to learn how to deliver Planet Earth to the next generation so that it will be a cleaner and more energizing place than the planet we inherited (Kamana and Escultura, 2011). Deuble and de Dear (2012) stated that green buildings, often defined as those featuring natural ventilation capabilities, i.e. low-energy or free-running buildings, were now at the forefront of building research and climate change mitigation scenarios. Advantages of green buildings are low in energy consumption, very good in indoor environment quality, low in emissions, highly efficient in waste management and environmentally friendly with building materials. There is difference between “green buildings” and “eco-construction”, where the concept of eco-construction is a part of the whole concept of green building. As forests, agricultural fields, and suburban and urban lands are replaced with

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impervious surfaces resulting from development, the necessity to recover green space is becoming increasingly critical to maintain environmental quality. Vegetated or green roofs are potential remedies for this problem. Establishing plant material on rooftops provides numerous ecological and economic benefits, including storm water management, energy conservation, mitigation of the urban heat island effect, and increases longevity of roofing membranes, as well as provides a more aesthetically pleasing environment in which to work and live. Furthermore, the construction and maintenance of green roofs provide business opportunities for nurseries, landscape contractors, irrigation specialists, and other green industry members while addressing the issues of environmental stewardship.

Because of building weight restrictions and costs, shallow-substrate extensive roofs are much more common than deeper intensive roofs. Therefore, the focus of this work is primarily on extensive green roofs (Getter and Rowe, 2006). More use of green roofs can reduce the severity of some of the problems of modern cities. Buildings that have roof gardens, in comparison with the building ordinary roofs, require less heating in winter and in summer require much less for cold, and can lead to significant savings in fuel consumption. The roof gardens have the potentials to act as insulation for the roof because of heat exchange with the outside environment (Wirth and Thomas, 2007). This feature can use a layer of porous soil and the plants of broad-leaved species are increased. As climate change impacts and food security needs, urban horticulture should play a vital role in producing the food via using green roof systems and at the same time securing the recycle of urban organic wastes to mitigate CO_2 emissions, and save the essential nutrients. Urban horticulture includes all horticultural crops grown for human consumption and ornamental use. Urban horticulture is not only working on producing large variety of vegetables, cereals, flowers, ornamental trees, aromatic vegetables and mushrooms, but also fighting for the climate change impacts, poverty, hungry, malnutrition and illness, to help food security, economy and social needs (FAO, 2012). In recently years, some problems in soil culture (such as salinity and unsuitable soil characteristics) and limitation of water resources in many countries, cause to expand soilless culture. Replacing soil growing systems with soilless growing for plants especially for cucumber, pepper, tomatoes and other vegetables cause control of plant nutrition and eliminate of plant diseases, that caused by soil (Olympios, 1999; Abdelraouf et al., 2014a).

Another fatal problem is the disability of getting enough energy supplies. Here, the problem of energy is a natural consequence of the unsustainable development of energy patterns followed during the last decades. To alleviate the severe suffering from shortage of water and energy sources, the suggested solutions should be innovative and sustainable. The use of solar energy can help in solving the energy shortage problem, especially Egypt lies in the Sun Belt region. Photovoltaic (PV) energy can be used efficiently in pumping water to agriculture purposes (Shouman et al., 2016). The water can be pumped efficiently using PV energy since there is a matching between the amount of water needed to be pumped and the solar radiation levels. In summer, as the water demand for agriculture purposes increase due to the hot weather, the solar radiation levels also increase in summer which can cover the energy requirement, with the same matching in winter. Figure 1 shows a schematic diagram of the water pumping system using PV energy. As shown in the figure, the PV water pumping system consists of the following main components: i) PV array which directly converts the sunlight into direct current (DC) electrical energy; b) DC/alternating current (AC) inverter to convert the generated DC energy into AC energy for driving an AC motor; c) AC motor and pump, to pump the required water for agriculture purposes (Khattab et al., 2016).

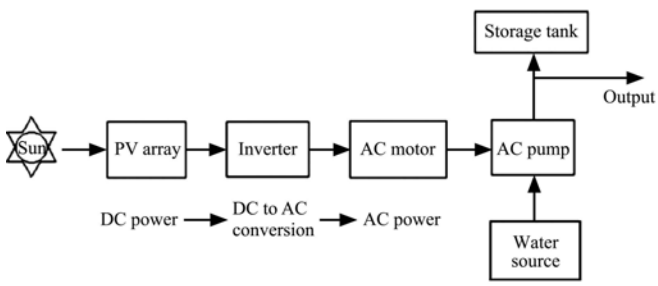

Figure 1 A schematic diagram of the water pumping system using PV energy

There are many new sources of water, which are not well exploited in agriculture such as recycling the drainage water of fish forming which rich with organic matter for agriculture use. Abdelraouf et al. (2014b) mentioned that using drainage water of fish ponds as new sources for irrigation for soybean crop will save 25% from minerals fertilizers under sprinkler irrigation system. Also, Abdelraouf and Hoballah (2014) reported that, reusing of drainage water of fish farming as a new resource for irrigation and rich with organic matter is very useful for arid regions and it could improve soil quality and crop productivity and reduce the total costs of fertilizers by adding minimum doses from minerals fertilizer and sprinkler irrigation system was the best irrigation system which could be used. One of these sources is the ablution water in the mosques where, Ministry of El-Awqaf actually began from few months ago. According to Egyptian Statistics Authority (2018) there are a large number of mosques were built by self-efforts of people under the supervision of the Egyptian Awqaf ministry and the total number of these mosques reached to 132809 and including 6327 mosques in Cairo. (https://www.youm7.com/story/2018/4/18/3749596).

The main goal of this study was to design a sustainable system to reuse ablution water as a new water resource in irrigation for sustainable crop production on the mosques roofs and pump it by sustainable new and renewable energy source using PV technology.

2 Materials and methods

2.1 Site parameters

Field experiments were conducted during two seasons 2015 and 2016 at mosque in Dokki region, Giza government (Latitude of 30°2'38"North, Longitude of 31°14'9"East). For optimum design for a PV system, it is very important to collect the meteorological data for the site under consideration. Although the solar radiation data has a great effect on the performance of PV systems, there are different other parameters needed such as, ambient temperature, relative humidity and wind speed. Table 1 summarizes the monthly mean climatic data for average two growing seasons for selected site. The data were obtained from "The Central Laboratory of Meteorology" which is related to The Ministry of Agriculture.

Table 1 The average data of maximum and minimum temperature, relative humidity, wind speed and monthly average solar radiation intensity on optimum tilted surface

Months	HC Air temperature (°C)		Relative humidity (%)		Aver. of Wind speed (m sec^{-1})	Monthly average solar radiation intensity (W m^{-2})
	Maxi.	Mini.	Maxi.	Mini.		
Jan.	21.4	6.5	83.4	21.6	6.3	4670
Feb.	25.0	6.3	82.6	22.8	6.5	5410
March	35.3	11.6	79.4	18.7	5.5	6240
April	38.1	11.5	79.0	20.8	7.1	6650
May	37.1	12.3	74.5	20.0	7.0	7030
June	39.4	9.6	78.3	19.8	6.5	7350
July	35.5	10.6	80.0	26.8	5.5	7410
Aug.	36.7	14.0	80.4	24.1	4.6	7390
Seb.	36.8	14.0	83.9	27.7	5.7	7080
Oct.	36.3	15.6	86.3	28.6	7.1	6470
Nov.	28.5	12.5	83.2	18.9	6.5	5200
Dec.	28.2	10.0	82.1	24.6	5.4	4540

2.2 Dimensions of mosque

Dimensions of the mosque roof in the present study were 16 m length, 12 m width and 5 m height as shown in Figure 2.

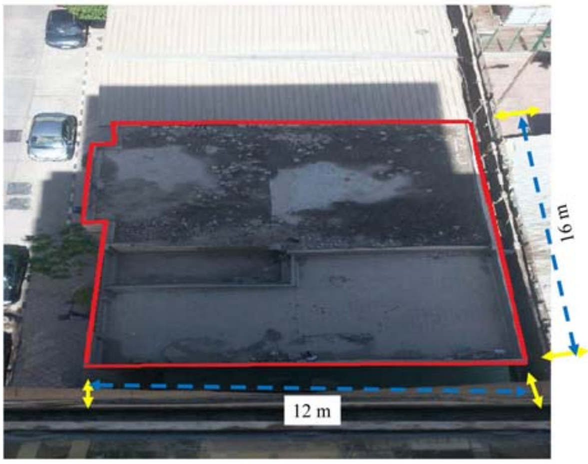

Figure 2 Dimensions of the mosque roof under study

2.3 Experimental design

Experimental design and treatments were split plots with two categories.

i) Systems of the green roof (traditional design): green roof using tap water in irrigation and using electric energy for pumping it;

ii) Sustainable design: green roof by reusing ablution water as a new water resource for irrigation and using PV energy for pumping it.

Each system has been studied for three cases according to the number of green layers as one, two and three green layers. The proposed systems have been plotted in Figures 3-8.

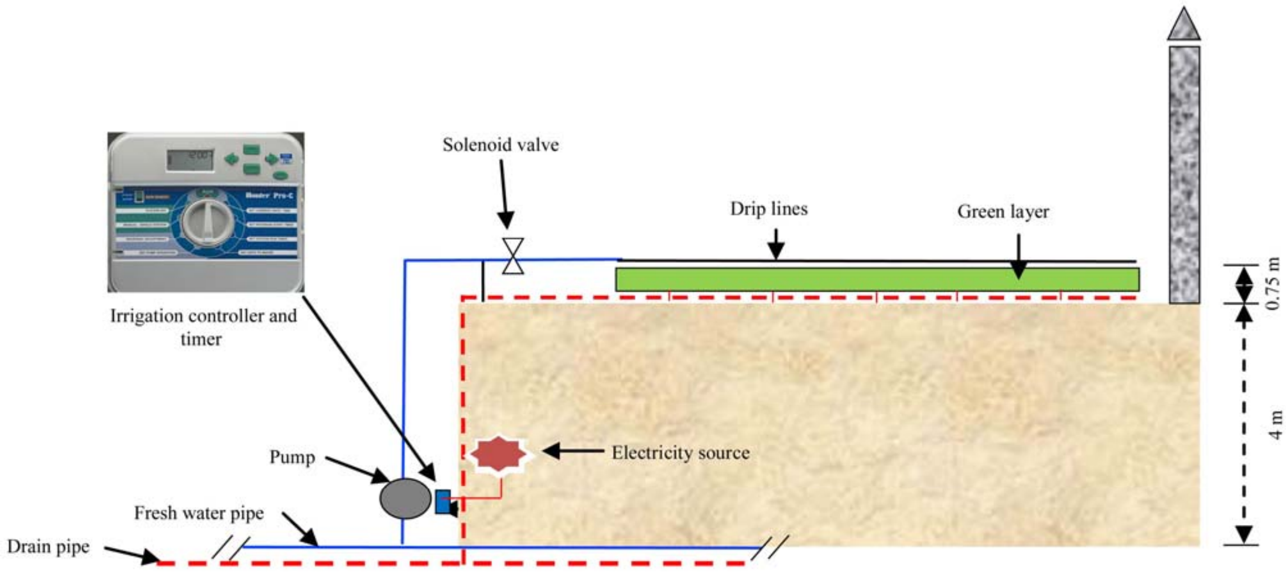

Figure 3 Traditional design with one green layer

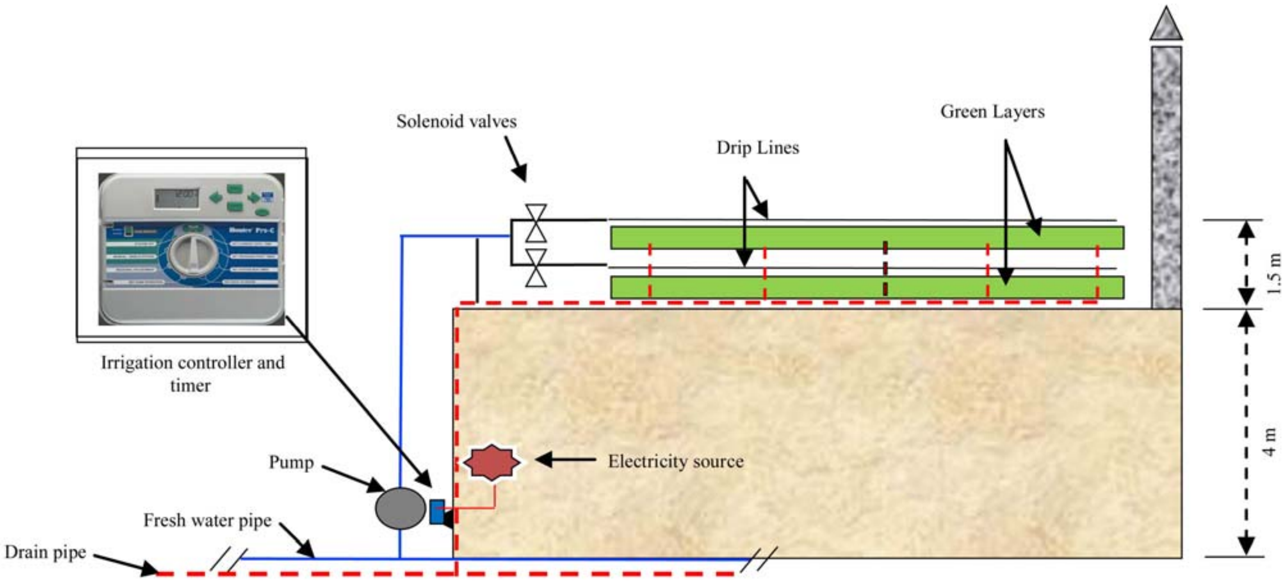

Figure 4 Traditional design with two green layers

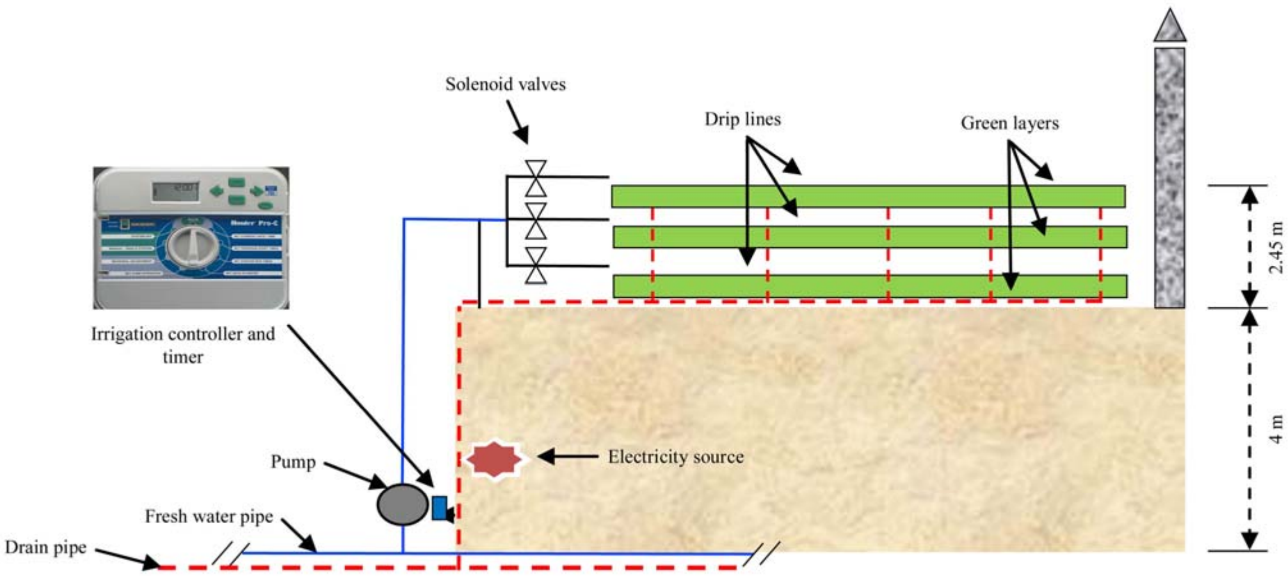

Figure 5 Traditional design with three green layers

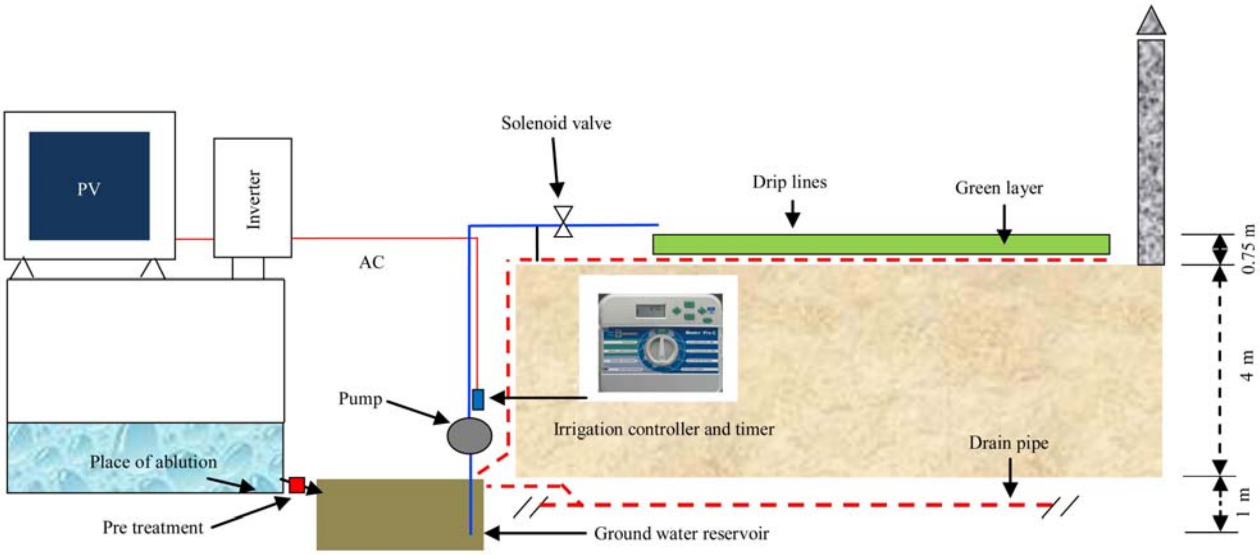

Figure 6 Sustainable design with one green layer

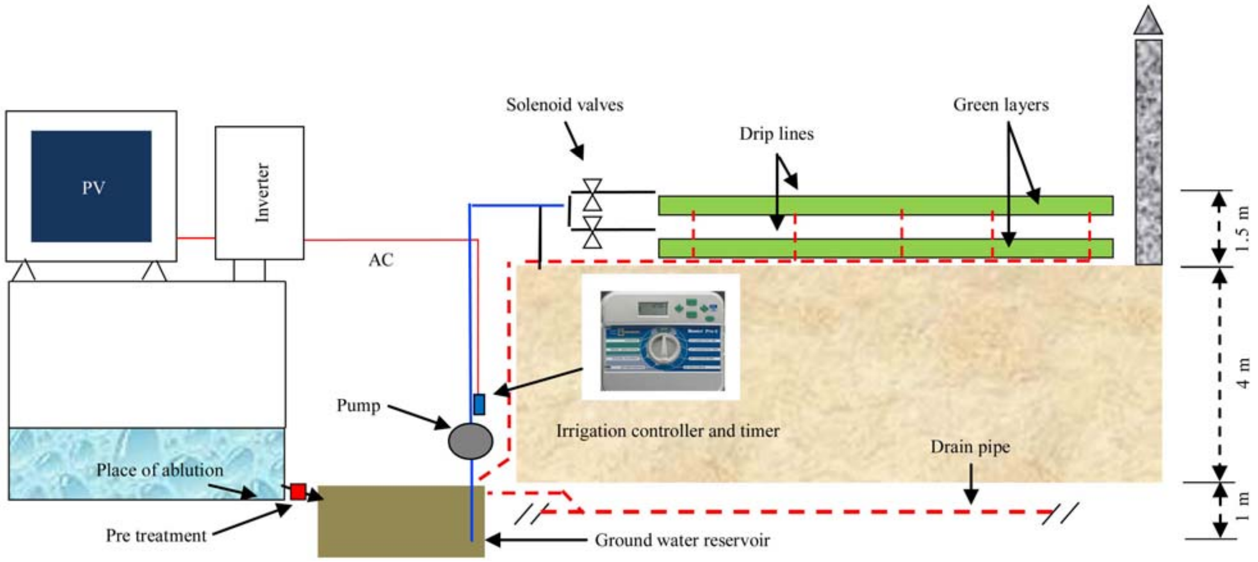

Figure 7 Sustainable design with two green layers

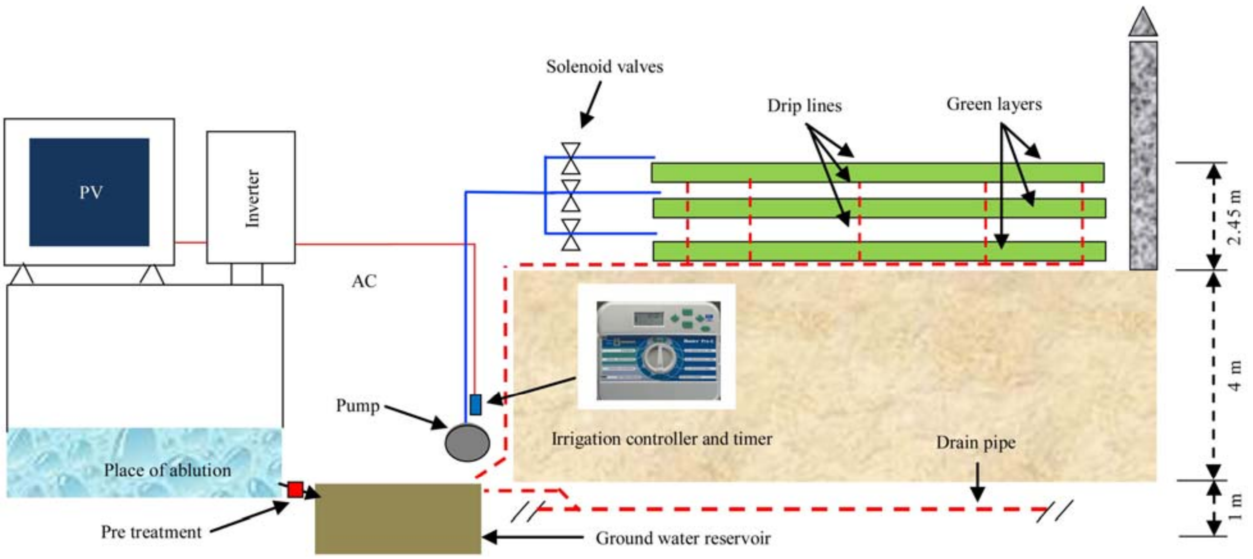

Figure 8 Sustainable design with three green layers

2.4 Media culture and system materials

The substrate mixture was peat moss: perlite (50:50 V/V). Closed system was used under the study and manufactured from wooden tables with dimensions of

120 × 120 × 25 cm^3 for traditional design in addition to other two wooden tables modified to carry multi green layers as shown in Figures 9-11. It was repeated in the ranks to cover 80% of the surface area of mosque roof. Effective and green surface area of mosque roof (EGSAMR) for one green layer is 154 m^2 (16 m ×12 m × 0.8 = 153.6 m^2 ≈ 154 m^2), for two layers is about 270 m^2 (154 + 154 ×0.75= 270 m^2) and for three layers is 347 m^2 (154 + 154 × 0.75 + 154 × 0.5 = 347 m^2). Black polyethylene (1 mm) was used to create the main gully which was filled by substrate mixture from peat moss: perlitt (50:50 V/V). A layer of 2-3 cm of gravel took a place in the bottom of gully bin for leaching the drainage water easily to drainage pipes.

2.5 Plant materials

Two crops were cultivated. Sweet pepper (*Capsicum annuum* L. cv. Reda) seedlings were transplanted on 1th May and harvested on 25th August, and potato tubers were sown two times per year, where the first time was 1th January and harvested on 25th April and the second time was 1th September and harvested on 20th December. All previous actions were repeated during the two growing seasons 2015 and 2016.

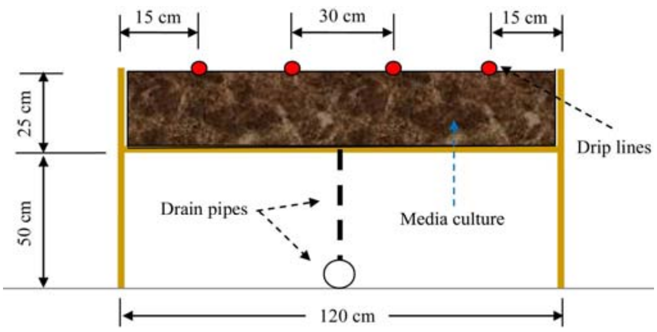

Figure 9 Design of wooden table for one green layer

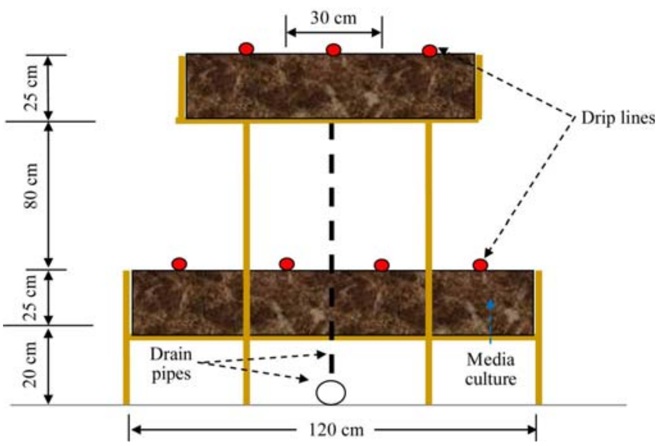

Figure 10 Design of wooden table for two green layers

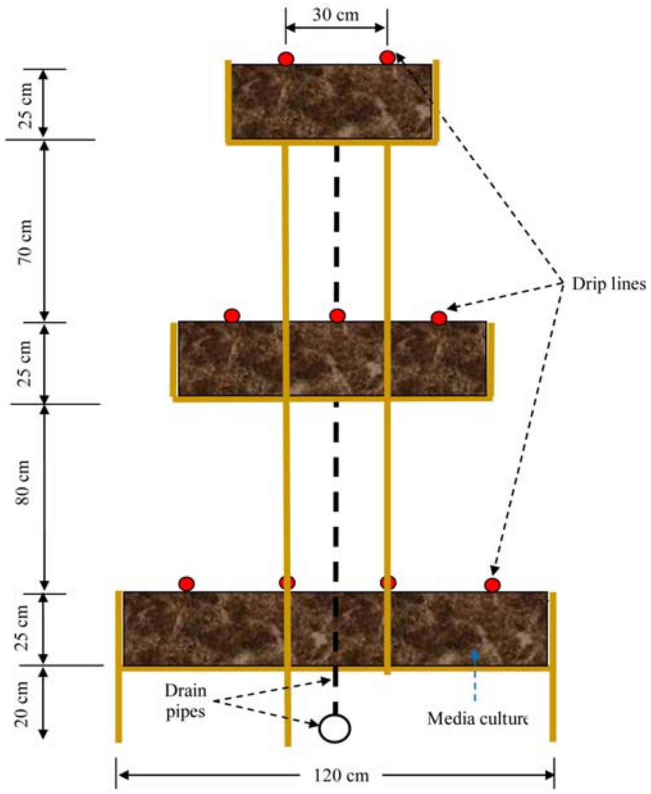

Figure 11 Design of wooden table for three green layers

2.6 Gray water treatment

In accordance with the laws of USA, the percentage of chlorine added to drainage water of the ablution was 1.45 mg m^{-3}. Chlorine has main roles when used for gray water treatment like removing unwanted substances in water by oxidation and effective sterilization in case of accidental contamination. Figure 12 shows an automatic device to install the percentage of chlorine in drainage water of the ablution.

Figure 12 Automatic device to install the percentage of chlorine in drainage water of the ablution

2.7 Irrigation requirements for selected crops

The irrigation water requirements for irrigating selected crops were based on the reference evapotranspiration equation of Penman-Monteith using daily data for site weather station of Dokki region and using the following equation to determine total water volumes for each treatment are reported in Table 2.

$$IRg = [(ET_o \times Kc \times Kr) / Ei] - R + LR \quad (1)$$

where, IRg is gross irrigation requirements (mm day^{-1}); ET_o is a reference evapotranspiration (mm day^{-1}). Figure 13 shows the average ET_o during the previous fifth years of 2015 for Dokki region, Kc is a crop factor (FAO 56), Kr is a ground cover reduction factor (values of Kr suggested by different authors (FAO, 1984), Ei is irrigation efficiency (%), R is water received by plant from sources other than irrigation, for example rainfall, (mm) and LR is amount of water required for the leaching of salts (mm).

Table 2 Irrigation water requirements and determining the main recourses for water and energy for each treatment.

Growing Seasons	Design Systems	No. of Green Layers	EGSAMR, m^2	Total Water Volume for specific area, m^3			Main Recourse of Irrigation Water	Main Recourse of Energy
				Potato1	Sweet pepper	Potato2		
2015	Traditional Design, TD	1 GL	154	88	73	81	Fresh water	Electricity
		2 GL	270	154	128	142	Fresh water	Electricity
		3 GL	347	198	164	183	Fresh water	Electricity
	Sustainable Design, SD	1 GL	154	88	73	81	Ablution water	PV
		2 GL	270	154	128	142	Ablution water	PV
		3 GL	347	198	164	183	Ablution water	PV
2016	Traditional Design, TD	1 GL	154	85	71	79	Fresh water	Electricity
		2 GL	270	149	124	139	Fresh water	Electricity
		3 GL	347	192	160	178	Fresh water	Electricity
	Sustainable Design, SD	1 GL	154	85	71	79	Ablution water	PV
		2 GL	270	149	124	139	Ablution water	PV
		3 GL	347	192	160	178	Ablution water	PV

Note: 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer

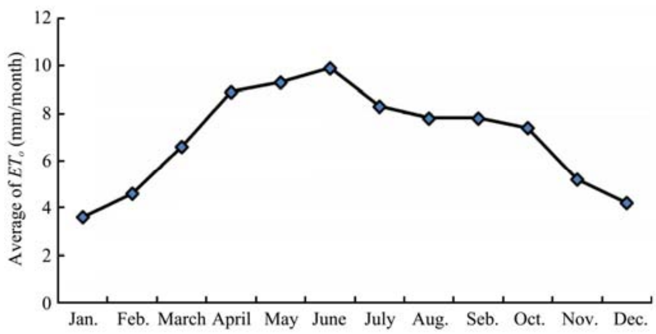

Figure 13 Average of ETo during the previous fifth years of 2015 for Dokki region

The suggestion crops were irrigated by using drippers of 4 l hr^{-1} capacity. The irrigation scheduled was programmed by using digital timer to determine the schedules and operation time of irrigation depend. Fertilization program for selected crops had been done according to the recommended doses throughout the growing season (2015 - 2016) under drip irrigation system.

Calculating maximum crop water requirements for effective and green surface area of mosque roof per day during the previous fifth years of 2015 (Maxi. CWR, Table 3) has been estimated by the following equation:

$$\text{Maxi.CWR } (m^3/\text{A1, A2, A3 } m^2 \text{ day}^{-1}) = [(\text{Maxi. } ET_o \times \text{Maxi. } Kc \times \text{Maxi. } Kr)/Ei] - R + \text{LR} \quad (2)$$

Table 3 Maximum crop water requirements for effective and green surface area of mosque per day during the previous fifth years of 2015

No.	Items of Equation	Maxi. CWR (m^3 day^{-1})		
		Potato1	Potato 2	Sweet paper
1.	Maxi. ET_o (mm day^{-1})		10	
2.	Maxi. Kc	1.15	1.15	1.05
3.	Maxi. Kr		1	
4.	Ei		0.95	
5.	R		No rainfall	
6.	LR		No R because the EC of ablution water is very small	
7.	A1: One green layer (m^2)		154	
	A2: two green layers (m^2)		270	
	A3: three green layers (m^2)		347	
	Maxi. CWR (m^3/A1/day)	1.68	1.66	1.54
	Maxi. CWR (m^3/A2/day)	2.94	2.91	2.65
	Maxi. CWR (m^3/A3/day)	3.78	3.74	3.47

Note: ET_o: Reference evapotranspiration (mm day^{-1}); Kc: Crop factor (FAO reference); Kr: Ground cover reduction factor, Values of Kr suggested by different authors (FAO, 1984); Ei: Irrigation efficiency, %; R: Water received by plant from sources other than irrigation, mm (for example rainfall) and LR: Amount of water required for the leaching of salts, mm; A: Effective and green surface area of mosque.

2.8 PV power needed for pumping irrigation water pumping

As shown in Figure 1, the PV pumping system mainly depends on the PV as a generating element for required energy to drive the irrigation pump via an electric motor to feed the required amount of water. According to the site information data (solar radiation intensities, wind speed and ambient temperatures, Table 1), the maximum irrigation water requirements for each crop (Equation (2) and Table 3) and maximum pumping head for each system (Figures 3-11), design of the PV water pumping system and its components can be carried out as well as system costs can be identified. Table 4 shows the design parameters of the sustainable design systems.

The electrical power needed for each case (W) can be calculated as follows (Preakis et al., 2017).

$$P = \frac{Q_P \times \rho \times g \times h}{\eta_P \times \eta_m \times 3.6 \times 10^6} \tag{3}$$

where, Q_P is the pump capacity (m^3 h^{-1}); ρ is the water density (kg cm^{-3}); g is the Earth gravity (9.8 m s^{-2}); h is the water head (m); η_P is the pump efficiency and η_m is the motor efficiency.

The required daily electrical energy (Wh day^{-1}) can be calculated using the daily required operating hours (*HO*, Table 4).

$$E_L = P \times HO \tag{4}$$

The PV area (m^2) and power (W) required for each system can be calculated as follows.

$$A_{PV} = \frac{E_L}{H \times \eta_{PV} \times T_C \times \eta_C \times \eta_B} \tag{5}$$

$$P_{PV} = A_{PV} \times H_{SC} \times \eta_{PV} \tag{6}$$

where, H is the irradiation on the system surface (Wh m^{-2} day^{-1}); T_C is the temperature coefficient of the PV module; η_{PV} and η_B is the efficiencies of the PV modules and batteries.

The required storage battery capacity can be calculated as follows.

$$B_E = \frac{P \times 2 \times N_C}{DOD \times \eta_C \times \eta_B} \tag{7}$$

where, N_C is the number of continuous cloudy days; *DOD* is the deep of battery discharge; η_C is the charge controller efficiency and η_B is the battery efficiency.

Equations (3)-(7) can be completely simulated the different components of the PV system such as PV power and battery capacity. The inverter rated power can be detected according to the required system power for each case (Equation (3)) multiplied by 1.25 for safety and the charge controller can be detected according to the system operating voltage and current. Table 4 summarizes the design parameters and the corresponding system components as well as system costs according to the current component commercial prices.

Table 4 Sustainable design (Ablution water + Solar Energy)

Items	EGSAMR for one layer, (154 m^2)	EGSAMR for two layers, (270 m^2)	EGSAMR for three layers, (347 m^2)
Total dynamic head, m	8	9	10
Water volume, m^3/day	1.68	2.94	3.78
Motor power, HP	0.027	0.055	0.085
Working hours, h	2	2	2
PV power, W	20	40	60
3 Batteries, Ah	12	25	45
Charge controller	5 A	5A	5A
Inverter, W	30 W	50 W	70 W
Cost (2015 prices), LE	500	750	1000
Cost (2016 prices), LE	600	1050	1300

2.9 Evaluation parameters

Yield of cultivated crops: at harvest, three random samples from effective and green surface area of mosque (the sample area of was 0.5 m × 0.5 m) were taken from each plot to determine yields in the mentioned area and then converted to yield for effective and green surface area of mosque roof.

Water productivity of cultivated crops (kg m^{-3}) was calculated according to James (1988) as follows.

$$WP = Ey/Ir \tag{8}$$

where, Ey is the economical yield (kg m^{-2}) and Ir is the amount of applied irrigation water (m^3 m^{-2} season^{-1}).

Energy productivity of cultivated crops (kg kWh^{-1}) was determined for the tested variables according to Abdel-Aal (2000) by following equation.

$$EP = \text{Total yield (kg)}/E_L \tag{9}$$

For economical evaluation, the social and environmental evaluation were collected from previous studies and the net income (LE year^{-1}) was determined according to Equation 10 (Rizk, 2007).

$$NI = \text{Total income for outputs} - \text{Total costs for Inputs} \tag{10}$$

where, total income for outputs (LE year^{-1}) is the financial value of final products for market crops. Total costs for inputs is the sum of i) cost of irrigation (it was computed according to Worth and Xin (1983) equation and market price level of years 2015 and 2016 for equipment and installation), ii) cost of wooden tables, iii) cost of materials structure, iv) cost of potato tubers and seeds, v) cost of peat moss and perlite, vi) cost of pest control, vii) cost of planting and viii) cost of harvesting.

The statistical analysis of data for two growing seasons was carried out according to Snedecor and Cochran (1981) and the values of least significant differences (L.S.D. at 5% level) were calculated to compare the means of different treatments.

3 Results and discussion

After designing the sustainable system and traditional system, installing the mechanical structure, purchasing the different components for each design and calculating the water and energy requirements for each treatment, the following results can be analyzed for the reusing of drainage water of ablution as a new water resource for sustainable crop production on the mosques roofs using by PV energy.

3.1 Gain yield of vegetable crops

The main goal of any development in agriculture is increasing the yields. Yield of potato1, Sweet pepper and potato2 were studied. Data in Figures 14, 15 and Tables 5, 6 represented the grain yield of cultivated vegetable crops under traditional design “TD” (using electricity in pumping fresh water for irrigation) and sustainable design “SD” (using PV energy in pumping ablution water for irrigation) for different number of green layers during the growing years 2015 and 2016. Yields vegetables crops under TD and SD were the same values but there was a positive impact for increasing the number of green layers. Maximum value of yield for Potato1, Sweet pepper and Potato2 occurred under 3GL with significant deference with 2GL and 1GL, and this may be due to the increase in total area of cultivated crops by the increasing number of green layers vertically, where EGSAMR equal 0.8 total surface area of the mosque and 1GL equal 154 m^2, 2GL equal 270 m^2 and 3GL equal 347 m^2.

3.2 Gain yield of the water productivity

Water productivity “WP” is an indicator of the effective use of irrigation water unit for increasing crop yield. Volume of reusing ablution water for cultivating the selected vegetables are measured during growing years 2015 and 2016 as shown in Figure 16. WP is calculated by dividing the total yield of vegetable crops by total applied irrigation water. WP values for vegetable crops during years 2015 and 2016 increased by increasing number of green layers but no significant difference for TD and SD were observed in Figures 17, 18 and Tables 5, 6. Maximum values of WP for vegetables were occurred under SD + 3GL and there was no significant deference observed. SD + 3GL treatment is recommended for reusing ablution water in irrigation and saving of fresh water especially under limitation of water resources in arid regions.

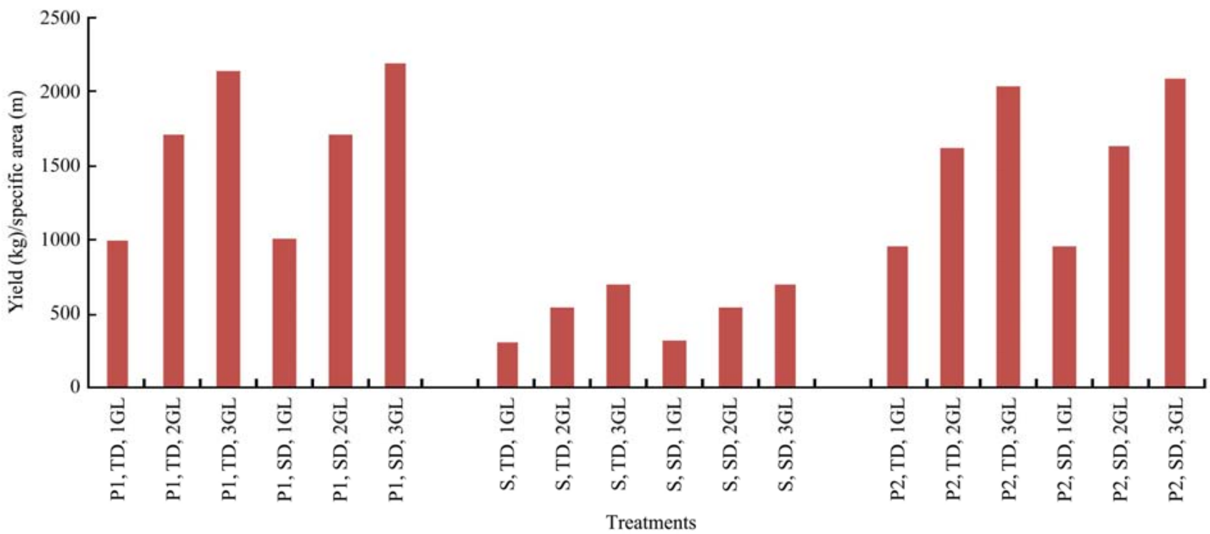

Figure 14 Effect of reusing the ablution water and pumping it by PV energy and number of green layers on the yield of vegetable crops for year 2015

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design.

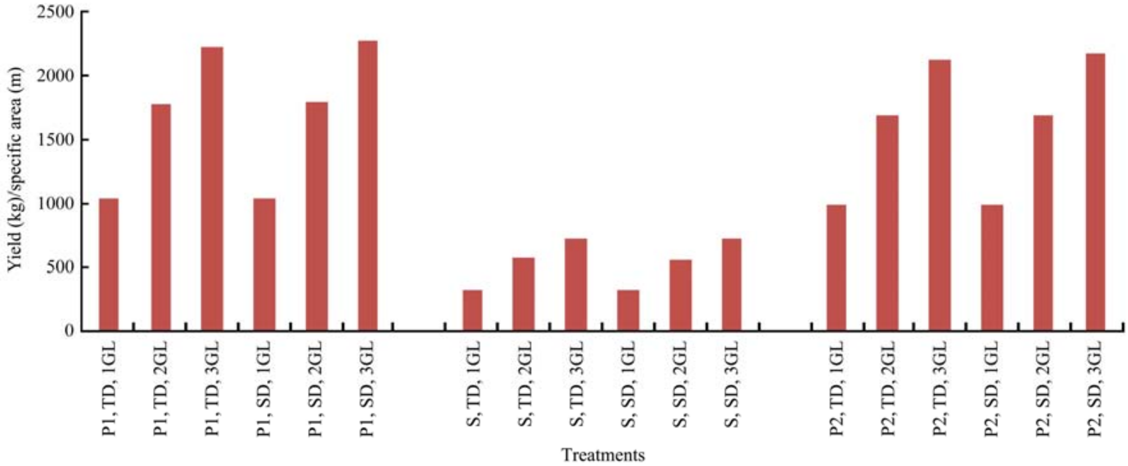

Figure 15 Effect of reusing the ablution water and pumping it by solar energy and number of green layers on the yield of vegetable crops for year 2016

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design.

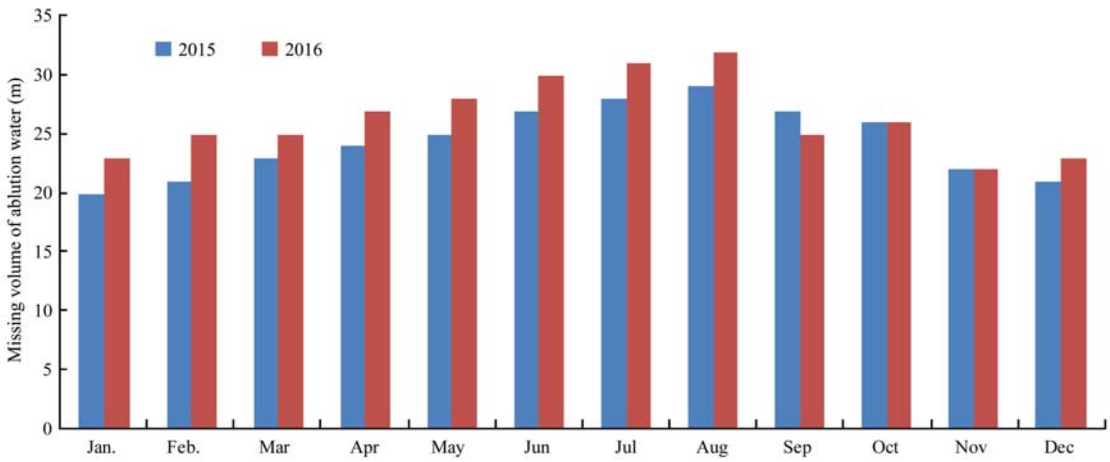

Figure 16 Average missing volume of ablution water (The amount this water was for ZOHAR, ASR and MAGHRIB periods in the governmental mosques and it has also been taken into consideration that there are eight days vacation during the month) during months of 2015 and 2016

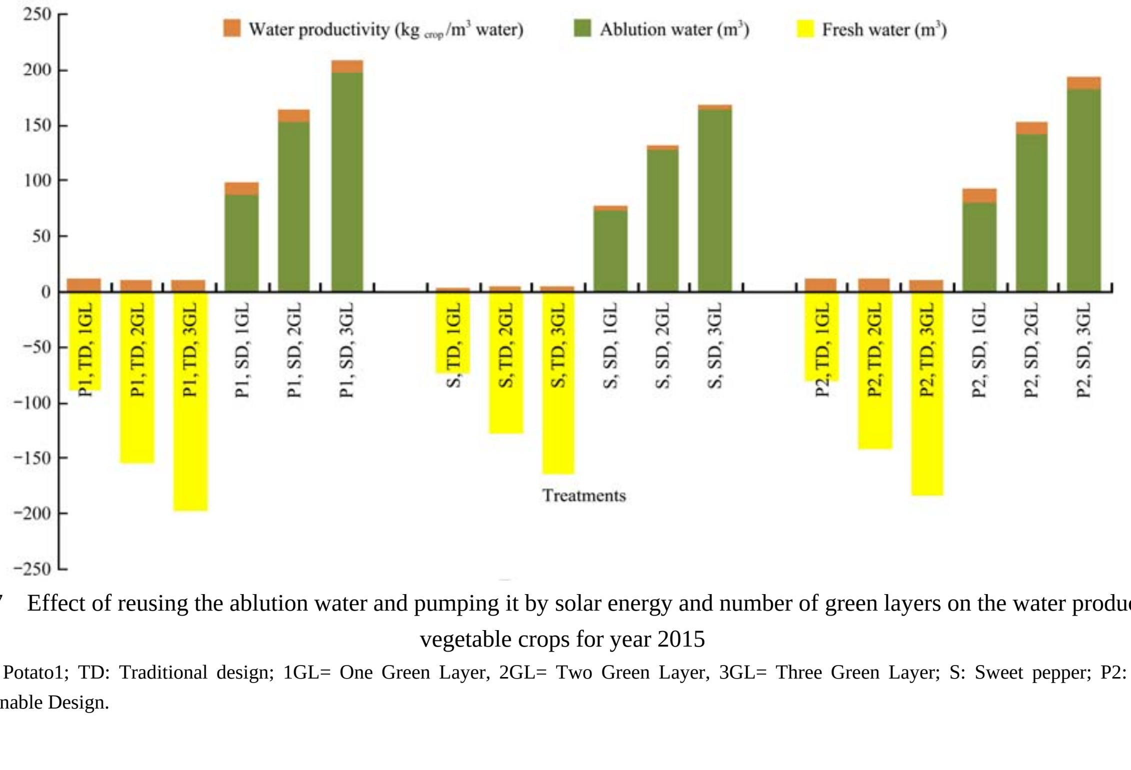

Figure 17 Effect of reusing the ablution water and pumping it by solar energy and number of green layers on the water productivity of vegetable crops for year 2015

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design.

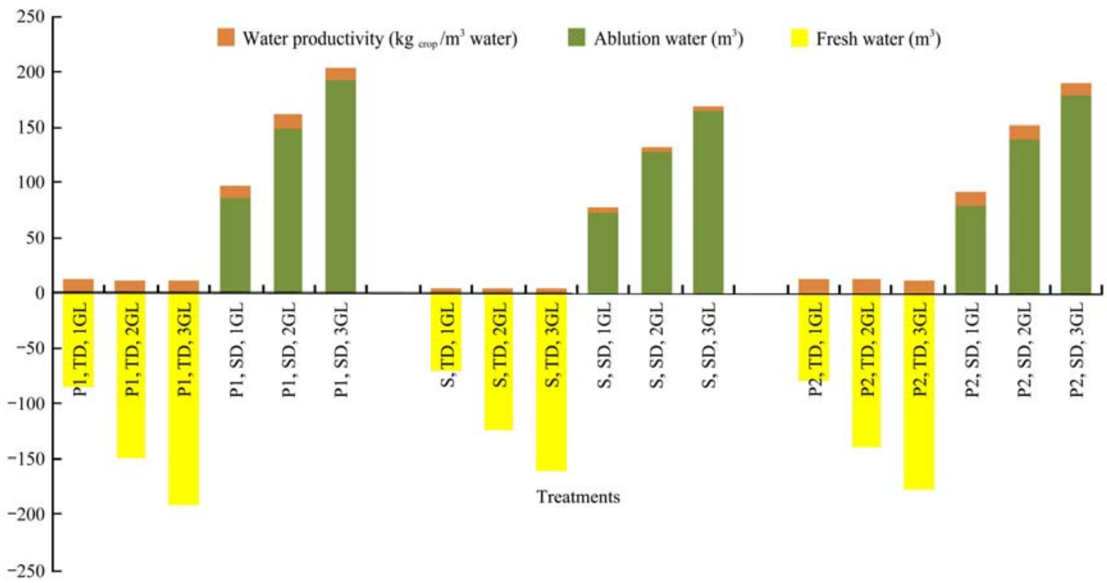

Figure 18 Effect of reusing the ablution water and pumping it by solar energy and number of green layers on the water productivity of vegetable crops for year 2016

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design.

Table 5 Effect of reusing the ablution water for irrigation by PV energy for different green layers on the yield, water and energy productivity of vegetable crops, 2015

Treatments	Effective and green surface area of mosque roof (m^2)	Yield of vegetable crops (kg/specific area (m^2))	Total Irrigation water requirements for specific area (m^3)	Available volume of ablution water (m^3)	Source of irrigation water (m^3)	Water productivity (kg_{crop}/m^3_{water})	Total energy consumption for pumping water (m^3)	Energy productivity (kg_{crop}/Kw. H)
P1,TD, 1GL	154	1001 e	88		– 88	11.38	1.57	639
P1,TD, 2GL	270	1710 d	154		– 154	11.10	2.11	809
P1,TD, 3GL	347	2150 b	198		– 198	10.86	4.31	499
P1,SD, 1GL	154	1005 e	88	293	+ 88	11.42	2.11	476
P1,SD, 2GL	270	1721 c	154	293	+ 154	11.18	4.30	400
P1,SD, 3GL	347	2200 a	198	293	+ 198	11.11	6.64	331
$LSD_{at\ 5\%}$		8.764						
S,TD, 1GL	303	305	73		– 73	4.18	1.30	235
S,TD, 2GL	270	541	128		– 128	4.23	1.75	309
S,TD, 3GL	347	696	164		– 164	4.24	3.57	195
S,SD, 1GL	154	308	73	293	+ 73	4.22	1.75	176
S,SD, 2GL	270	540	128	293	+ 128	4.22	3.57	151
S,SD, 3GL	347	700	164	293	+ 164	4.27	5.52	127
$LSD_{at\ 5\%}$		NS						
P2,TD, 1GL	154	951 d	81		– 81	11.74	1.43	664
P2,TD, 2GL	270	1625 c	142		– 142	11.44	1.93	840
P2,TD, 3GL	347	2043 b	183		– 183	11.16	3.94	519
P2,SD, 1GL	154	955 d	81	293	+ 81	11.79	1.93	494
P2,SD, 2GL	270	1635 c	142	293	+ 142	11.51	3.94	415
P2,SD, 3GL	347	2090 a	183	293	+ 183	11.42	6.09	343
$LSD_{at\ 5\%}$		14.92						

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design; (-): means that source of irrigation water from fresh water ; (+) means that source of irrigation water from drainage of ablution water

3.3 Gain yield of the energy productivity

Energy productivity “EP” is an indicator of effective use of energy unit for increasing crop yield. EP decreased by increasing consumed energy, while consumed energy increased by increasing number of operation hours, and operation hours increased by increasing water pumping volume for each treatment. In the present study, minimum values of EP are occurred under SD + 3GL for each crop as shown in Figures 19, 20 and Tables 5, 6.

3.4 Economical evaluation for reusing the ablution water using PV energy

Economical evolution is the most important indicator for any development. The data in Figure 20 and Table 7 presented the effect of system design (TD and SD) and number of green layers on net income "NI" per year. The values of NI increased by the increasing number of green layers but not affected by kind of water resource for 2015 and 2016. This might be due to the increasing yields of vegetable by increasing number of green layers. Maximum values of net income occurred under the following conditions TD + 3GL and SD + 3GL treatment. Additionally, no significant difference observed between them for each crop during growing years 2015 and 2016. Although the cost of consumption energy for solar energy was higher than the cost of electricity consumption especially in study years 2015 and 2016 as indicated in Table 7, the using of PV energy was still recommended according to the lifetime of PV energy components (20 years lifetime). Figure 21 indicated that the positive impact for using PV energy in short term after 5 years would give us the same cost for using electricity. After 5 years, the cost of PV energy consumption would be lower than the cost of electricity consumption if the best treatments SD + 3GL and TD + 3GL were compared. Thus, SD + 3GL design was highly recommended to apply for increasing the NI and improving the environmental performance.

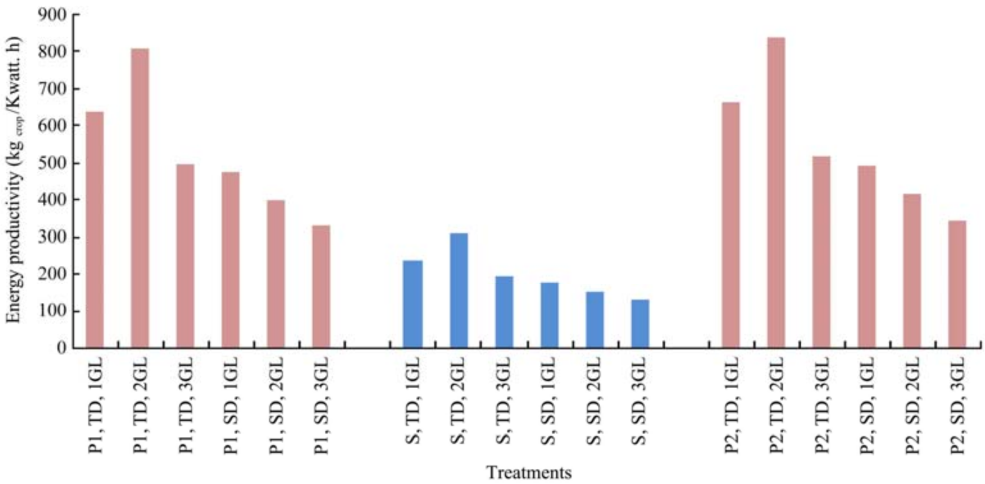

Figure 19 Effect of reusing the ablution water and pumping it by solar energy and number of green layers on the energy productivity of vegetable crops for year 2015

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design.

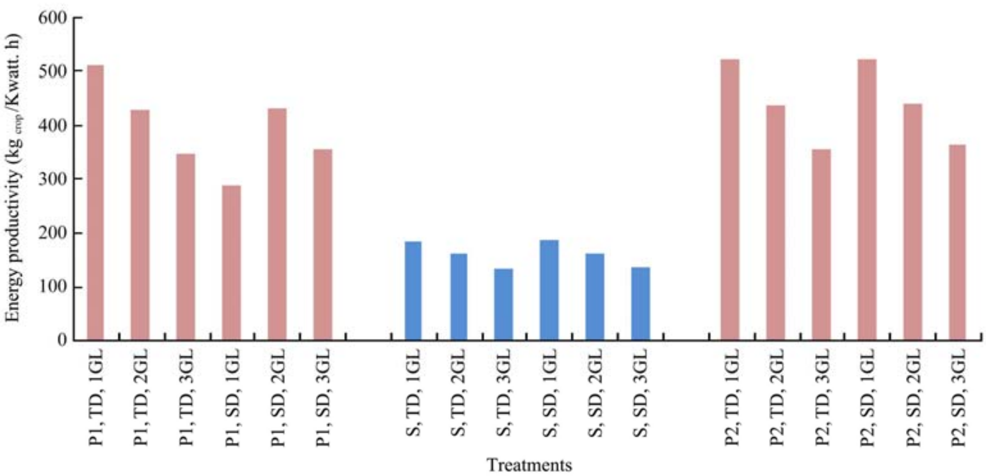

Figure 20 Effect of reusing the ablution water and pumping it by solar energy and number of green layers on the energy productivity of vegetable crops for year 2016

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design.

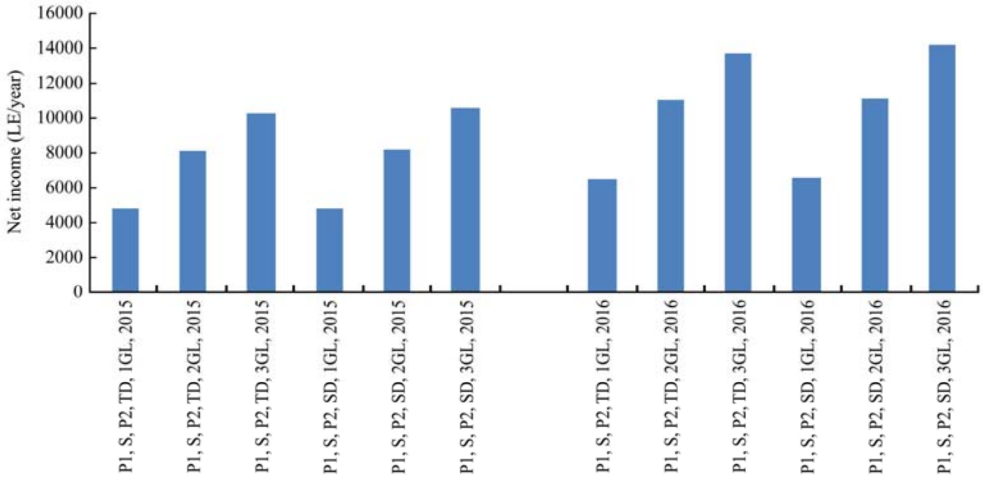

Figure 21 Economical evaluation for reusing the ablution water and pumping it by solar energy on the net income per year for cultivation of mosques roofs for years 2015 and 2016

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design.

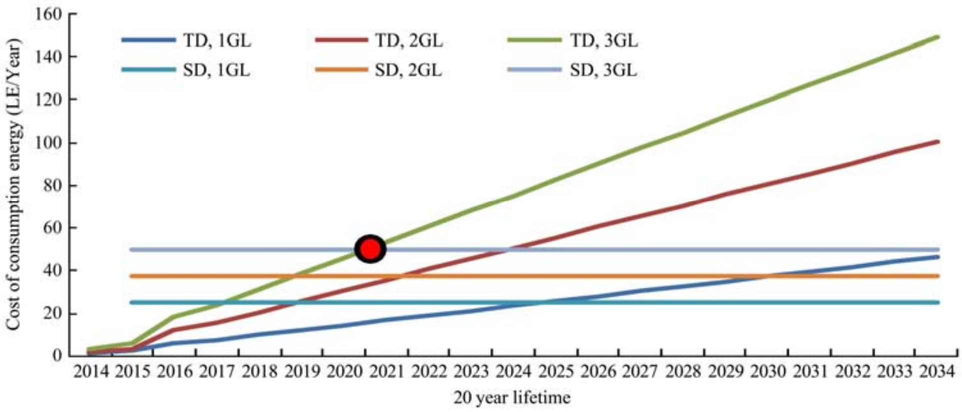

Figure 22 Effect of positive impact of solar energy on the cost of consumption energy based on 20 year lifetime

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design.

Table 6 Effect of reusing the ablution water for irrigation by PV energy for different green layers on the yield, water and energy productivity of vegetable crops, 2016

Treatments	Effective and green surface area of mosque roof (m^2)	Yield of vegetable crops (kg/specific area, m^2)	Total Irrigation water requirements for specific area (m^3)	Available volume of ablution water (m^3)	Source of irrigation water (m^3)	Water productivity (kg_{crop}/m^3_{water})	Total energy consumption for pumping water (m^3)	Energy productivity (kg_{crop}/Kw. H)
P1,TD, 1GL	154	1041 e	85		– 85	12.25	2.03	512
P1,TD, 2GL	270	1778 d	149		– 149	11.94	4.14	429
P1,TD, 3GL	347	2236 b	192		– 192	11.65	6.40	349
P1,SD, 1GL	154	1045 e	85	317	+ 85	12.30	2.03	514
P1,SD, 2GL	270	1790 c	149	317	+ 149	12.01	4.14	432
P1,SD, 3GL	347	2288 a	192	317	+ 192	11.92	6.40	357
$LSD_{at\ 5\%}$		8.64						
S,TD, 1GL	303	317	71		–71	4.47	1.71	185
S,TD, 2GL	270	563	124		–124	4.54	3.49	161
S,TD, 3GL	347	724	160		–160	4.52	5.39	134
S,SD, 1GL	154	320	71	317	+ 73	4.51	1.71	187
S,SD, 2GL	270	562	124	317	+ 128	4.53	3.49	161
S,SD, 3GL	347	728	160	317	+ 164	4.55	5.39	135
$LSD_{at\ 5\%}$		NS						
P2,TD, 1GL	154	989 d	79		–79	12.52	1.89	522
P2,TD, 2GL	270	1689 c	139		–139	12.15	3.86	438
P2,TD, 3GL	347	2124 b	178		–178	11.93	5.96	356
P2,SD, 1GL	154	993 d	79	317	+ 79	12.57	1.89	524
P2,SD, 2GL	270	1700 c	139	317	+ 139	12.23	3.86	441
P2,SD, 3GL	347	2174 a	178	317	+ 178	12.21	5.96	365
$LSD_{at\ 5\%}$		11.01						

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design; (-): means that source of irrigation water from fresh water; (+) means that source of irrigation water from drainage of ablution water.

Table 7 Economical evaluation for reusing the ablution water as a new source for irrigation and pumping it by solar energy, 2015 and 2016

Treatments	*Cost of irrigation, LE	**Cost of consumption energy (LE/Year)	*Cost of wooden tables and structure components, LE	**Cost of potato tubers and seeds, LE	*Cost of peat moss and perlite, pest control LE	*Cost of planting and harvesting, LE	Total costs for inputs, LE	Total income for output, LE = Yield* Price	Net income (LE/year)
P1,S,P2,TD, 1GL, 2015	250	2	1800	250	1560	300	4162	9028	4866 e
P1, S,P2,TD, 2GL, 2015	438	3	3170	438	2735	526	7310	15502	8192 d
P1, S,P2,TD, 3GL, 2015	563	6	4055	563	3515	575	9277	19554	10280 b
P1, S,P2,SD, 1GL, 2015	260	25	1800	250	1560	300	4195	9071	4876 e
P1, S,P2,SD, 2GL, 2015	445	38	3170	438	2735	526	7352	15584	8232 c
P1, S,P2,SD, 3GL, 2015	570	50	4055	563	3515	575	9328	19960	10630 a
LSD $_{\text{at 5\%}}$									17.75
P1,S,P2,TD, 1GL, 2016	280	6	2000	380	2100	400	5166	11736	6570 f
P1, S,P2,TD, 2GL, 2016	490	12	3506	666	3681	701	9056	20153	11100 d
P1, S,P2,TD, 3GL, 2016	630	18	4500	856	4731	901	11636	25420	13780 b
P1, S,P2,SD, 1GL, 2016	300	25	2000	380	2100	400	5205	11792	6587 e
P1, S,P2,SD, 2GL, 2016	510	38	3506	666	3681	701	9102	20259	11160 c
P1, S,P2,SD, 3GL, 2016	650	50	4500	856	4731	901	11688	25948	14260 a
LSD $_{\text{at 5\%}}$									3.522

Note: P1: Potato1; TD: Traditional design; 1GL= One Green Layer, 2GL= Two Green Layer, 3GL= Three Green Layer; S: Sweet pepper; P2: Potato 2; SD: Sustainable Design; *: Cost based on 20 year lifetime; **: Annually cost; [400 Litter peat moss = 250 LE and 100 Litter perlite = 100 LE based on 2015 prices]; [400 Litter peat moss = 300 LE and 100 Litter perlite = 140 LE based on 2016 prices]; [1 Kwatt . h = 0.25 LE, 0.5 LE , 1 LE and will increase to 1.4 LE for 2014, 2015, 2016 and 2017]

4 Conclusion

To alleviate severe suffering from a shortage of water and energy sources, suggested solutions should be innovative and sustainable. There are many new water resources that have not been well exploited in agriculture. One of these resources is the ablution water in the Egyptian mosques. This new resource can be managed by photovoltaic energy, as Egypt has good weather with high rates of solar radiation levels which can reach up to 3000 hours/year.

The process of pumping out drainage water of new water resource for agriculture by using PV energy is a good alternative in terms of sustainable development. Applying sustainable design which powered by PV energy will create new opportunities work for young people all over the country. Also increasing the green roofs area by reusing ablution water and managed it by PV energy will improve from environmental performance, such as: i) using the PV energy to run as a renewable source and sustainable alternative, ii) to reduce the amount of pollutants in the air, iii) to lead cultivation roofs to increase the proportion of oxygen and reduce the proportion of carbon dioxide from air cities, and iv) to minimize the impact of the island warm (Urban Heat Island).

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