RECENT IRRIGATION SCHEDULING TECHNIQUES FOR IMPROVING WATER USES IN LANDSCAPING

Osama M.A. Beder

Lecturer, Agricultural Engineering Department, Faculty of Agriculture
Ain Shams University, Cairo, Egypt
E-mail: osamabeder@yahoo.com

ABSTRACT

Global Climate Change (GCC) and its attributed water scarcity phenomena under arid and semi-arid conditions lead to decrease water income per capita and increase the water challenges allover the counterpart systems in general and agricultural systems in particular. Moreover, landscaping projects are considered as enhanced water consumptive use more than on farm projects. In addition, scheduling irrigation plays a crucial role in increasing water uses in the agricultural system, but it needs a highly qualified technique and attributed management practices to achieve its objectives. Therefore, the objective of this study was to estimate the irrigation water and energy savings in landscaping under different irrigation scheduling techniques.

Results revealed that scheduling practices based on the actual instantaneous microclimate data based on fully automated turf irrigation systems by using weather station could maximize the irrigation water use efficiency and enhance the irrigation water amount saving by about 43.74 % more than the traditional ways of scheduling, either that based on the design concepts and background or that based on the average values observed by Central Laboratory of Agricultural Climate (CLAC). In addition, data revealed that application of recent scheduling techniques can save about 36.7 % and 62 % of the seasonally operational costs and energy requirements, respectively.

Keywords: Irrigation, Scheduling, Weather station, Turf landscaping

INTRODUCTION

Climate Global drought Change (CGC) and attributed effect continues to affect the entire counterpart systems in general and agricultural systems in particular. Moreover, it reduces delivery quotas or water restrictions into the availability of water for crops and landscapes, and that means that they have more to do. Innovation, recycled water and efficient irrigation are all part of the new dialogue (Attaher, 2009). Meanwhile, the economy suffered a slowdown, due to legislative regulators. Therefore, an economic impact study will help us understand and convey our industry's importance. UC Santa Cruz (2009) stated that a task force identified four key recommendations for water use reduction, and methods to achieve that can be described as follows:

i- Recommended Actions for Water Use Reductions

1. Establish water use targets for specific types of water uses
2. Provide actually daily and monthly water use data to key water uses
3. Implement initial education – awareness campaign
4. Continue to accelerate high priorities of water conservation.

ii- Primary Methods to Achieve Water Use Reduction Targets

1. Operational adjustments by field managers and maintenance personnel
2. Education and outreach to promote water conservation behavior
3. Equipment and physical changes to fixtures and hardware
4. Feedback forum for monitoring used data with users.

Calculation of actual reference evapotranspiration based on boundary field agro-climate data can save water by optimizing the applied amount of irrigation water instead of guessing of how much water to add based on human experiences and average data of estimation, save money in agricultural and landscaping repairs caused by excessive watering and increases the output quality due to protection from excessive water UC (2009).

Moreover, Awady et al. (2003) and IA (2005) stated that instead of the crop coefficient (k) for field agriculture for efficient estimation of vegetation cover- water requirement, a landscape coefficient K_L is suggested by the Irrigation Association (IA) and Awady et al., 2003. The estimated K_L under different macro-climate conditions are tabulated in Tables (1) and (2). Moreover, it can be calculated according to the following formula:

$$K_L = K_s \times K_{mc} \times K_d \tag{1}$$

where:

K_L = Landscape coefficient (dimensionless).
K_s = Adjustment factor representing characteristics for a particular plant species (dimensionless).
K_{mc} = Adjustment factor for microclimate influences upon the planting (dimensionless).
K_d = Adjustment factor for plant density (dimensionless).

One problem with this approach is that each K factor is essentially an estimate even when based upon field research with each of the component factors changing with season. Even short term changes can alter estimates, especially in more humid climates where rainfall and considerable variations in solar radiation and humidity can occur in short time periods and over a landscape, (Carrow et al., 2002).

Castello et al. (1993) based plant water requirement on ET_o as a reference to a cool-season grass species with a specified height (typically 3 to 6 inches tall, 7.62-15.24 cm) under particular growing conditions. This reference must be adjusted to better fit the plant water requirement of a specific plant species in the landscape setting. The landscape coefficient K_L is used to adjust ET_o to determine the plant water requirement (PWR) of a specific plant species:

$$PWR = ET_o \times K_L \quad (2)$$

where:

PWR = Plant water requirement (in. or mm/period)
ET_o = Reference ET based on cool-season grass (in. or mm/period)
K_L = Landscape coefficient (dimensionless).

Table 1: Species Factor (K_s) for different plant types

Vegetation	High	Average	Low
Trees[1]	0.9	0.5	0.2
Shrubs[1]	0.7	0.5	0.2
Ground cover[1]	0.9	0.5	0.2
Mixture of trees, shrubs, and ground cover[2]	0.9	0.5	0.2
Cool Season Turfgrass	--	0.8	--
Warm Season Turfgrass	--	0.6	--

[1] The tree, shrub, and groundcover categories listed are for landscapes that are composed solely or predominantly of one of these vegetation types.

[2] Mixed plantings are composed of two or all three vegetation types (i.e., where a single vegetation type does not predominate).

Source: Awady et al., 2003 and IA, 2009

Table 2: Microclimate Factor (K_{mc}) for different plant types

Vegetation	High	Average	Low
Trees	1.4	1.0	0.5
Shrubs	1.3	1.0	0.5
Ground cover	1.2	1.0	0.5
Mixture of trees, shrubs, and ground cover	1.4	1.0	0.5
Turfgrass	1.2	1.0	0.8

Source: Awady et al., 2003 and IA, 2009

Table 3: Density Factor (K_d) for different plant types

Vegetation	High	Average	Low
Trees	1.3	1.0	0.5
Shrubs	1.1	1.0	0.5
Ground cover	1.1	1.0	0.5
Mixture of trees, shrubs, and ground cover	1.3	1.0	0.6
Turfgrass	1.0	1.0	0.6

Source: Awady et al., 2003 and IA, 2009

Meanwhile, IA (2000b) gave the following values (Table 4) for the ET_o, for mid-summer grasses. However, when actual data are available from weather stations (such as CIMIS in California), they must be used for more coherent results.

Table 4: ET_o values based on climatic conditions, IA, 2000b

Climate	Temp. °F/ R.H. %	ET_o (max. inch/day; mm/day)
Cool humid	<70 / >50	0.1-0.15; 2.54-3.81
Cool dry	<70 / <50	0.15-0.2; 3.81-5.08
Warm humid	70-90 / >50	0.15-0.2; 3.81-5.08
Warm dry	70-90 / <50	0.2-0.25; 5.08-6.35
Hot humid	>90 / >50	0.2-0.30; 5.08-7.62
Hot dry	>90 / <50	0.3-0.45; 7.62-11.43

Several researches had been carried out and achieved fine results towards maximizing irrigation water use efficiency under different climate conditions (Arafa, 2009 and Allen et al., 1998), but unfortunately all these researches had been conducted under field cops and orchard conditions. On the other hand, a few researches had been carried out under landscaping pattern conditions, which are considered as much consumptive water uses under diverse climate conditions all over the world, Awady et al. (2003) and WUCOLS (2000). Moreover, a vital mistake of estimating the landscaping cover patterns-water requirements is that the estimation is based on the design concepts and background are the project area.

Therefore, the objective of this study was to estimate the irrigation water and energy saving in landscaping under different irrigation scheduling techniques.

MATERIALS AND METHODS

Field experiments were carried out at landscaping project located at New Cairo City in season 2007-2008, which represents sandy soil conditions. A filtered fresh water (based on media and screen filters) with high quality EC of about (550 ppm) was used as a source of irrigation water for the irrigation requirements of a total landscaping area of about (32000 square meters). A permanent weather station located at the area of study indicates the climate to be typically Mediterranean. Annual rainfall is about 50 mm of about 90 rainy days (mostly during winter, generally between November and January. Rainfall amounts had been considered in the irrigation scheduling activities (CLAC, 2008). There are approximately 12 hours of direct sunlight during summer with possible temperatures above 35°C.

The layout of the experimental area, applied turf irrigation systems and applied recent techniques for estimating landscaping cover patterns-water requirements are shown in Fig. 1. However, the layout of experiments for achieving the objective of this research had been conducted based on split –split design with three replicates.

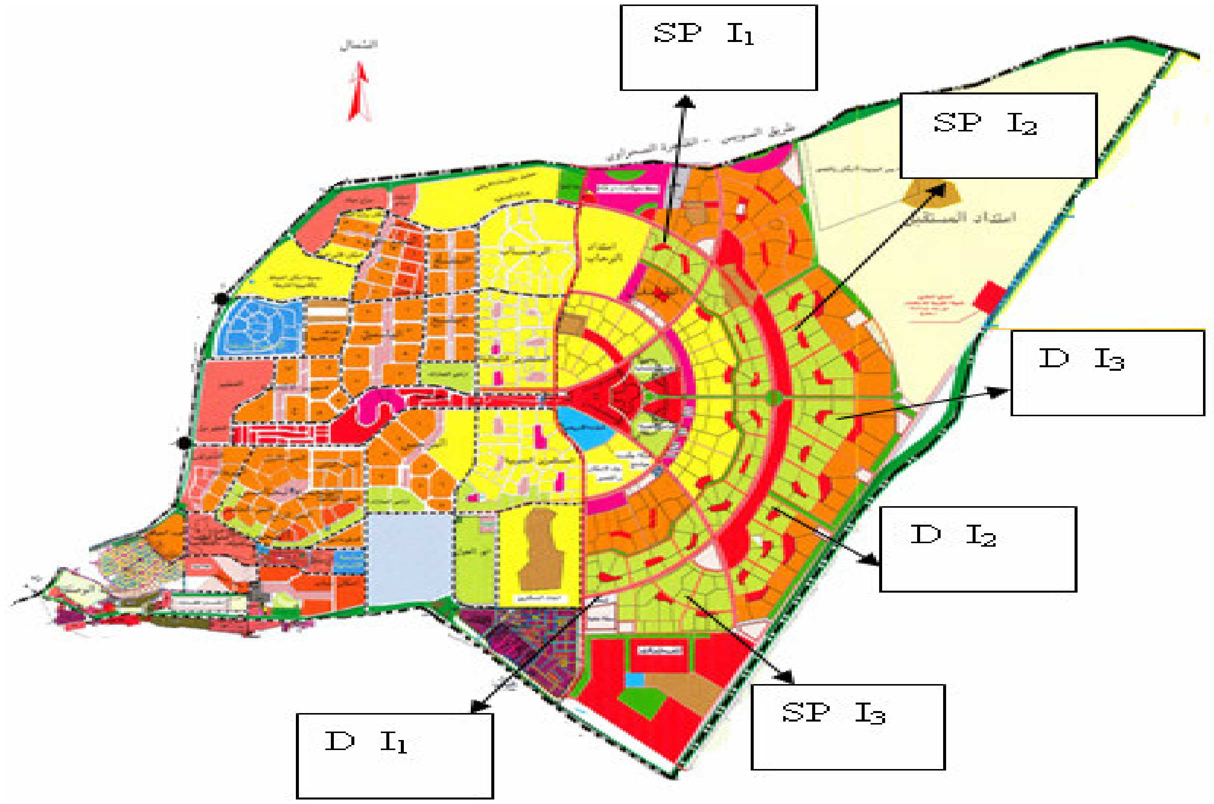

Fig. (1): Layout of the turf irrigation systems and attributed recent scheduling techniques in the experimental site

SpI$_1$: Based on design concepts and background, for sprinkler area
SpI$_2$: Based on average data of microclimate, collected from CLAC, for sprinkler area
SpI$_3$: Based on the actual microclimate data, collected with weather station, for sprinkler area
DI$_1$: Based on design concepts and background, for drip area
DI$_2$: Based on average data of microclimate, collected from CLAC, for drip area
DI$_3$: Based on the actual microclimate data, collected with weather station, for drip area

1. Turf irrigation systems

The experimental site was equipped with two turf irrigation systems (sprinkler and drip) for the landscaping patterns cover-water and nutrient requirements. However, technical specifications of the irrigation systems could be listed as follows:

i. Control head units (CHU):

CHU was located at the water source (supply). It consisted of two centrifugal pumps 6"/ 6" with about 75% volumetric efficiency, driven by electrical motor with about 30 hp for each pump. The discharge of the pumping unit is 100 m^3/h with 60 m head, sand media filter 48" (three tanks) back flow prevention device, pressure regulator, pressure gauges, flow meter, control valves and chemical injection equipment.

ii. Mainlines:

Main line was 160 mm diameter (OD) UPVC pipe, 10 bar operating pressure, used to carry water from the pumping unit to sub-mains. It is buried at 1 m under the ground surface.

iii. Sub-main and manifold line:

110 mm and 90mm in diameter (OD) UPVC pipes used for converting the water to laterals lines.

iv. Sprinkler irrigation system:

The sprinkler was a high level impact, corrosion resistant body, with stem and nozzle. Pop-up height is 4". The operating pressure of sprayer is 2 bar, discharge is 0.8 m^3/h with 32 mm/h precipitation rate, low angle sprays with shorter radius for narrow grass areas.

v. Drip irrigation system:

A self compensating pressure emitter with discharge rate of about 4 LPH at 1 bar operating pressure and spacing between emitters on dripper-line was 50 cm and 50 cm lateral spacing and 50 m maximum length for shrubs sand groundcovers, using bubbler self compensating type having a fixed flow under a pressure range of 20 to 90 PSI and discharges 0.25, 0.5, 1.0 and 2.0 GPM flow rates for trees and palms.

2. Irrigation scheduling and attributed techniques

Appropriate irrigation scheduling can be conserved and maintained that avoid plant water stress. To achieve this objective, specific and fine data of soil, plant and climatic parameters could be gathered and analyzed at specific field conditions. Therefore, micro-climatic data had been collected with three scheduling techniques (I_1: based on the design concepts and background; I_2: based on the average monthly microclimatic data observed by CLAC, and I_3: based on the actual instantaneous microclimate data, which had been collected from the located weather station at the experimental site). After then, all these data had been crossed to the equation of modified Penman–Monteith, recommended by FAO for estimating the reference evapotranspiration of different vegetation covers under diverse field conditions allover the world. This scheduling method had been described by Allen et al. (1998). After then, the average ET_o had been used for estimating the landscaping cover-water and irrigation requirements for different cover patterns at the experimental site, based on the following formula:

$$ET_L = ET_o * K_L \qquad (3)$$

$$I.R. = Et_L/E_a \qquad (4)$$

where: ET_L is the cover pattern-water requirement; K_L is the landscaping plants coefficient; I.R. is the irrigation requirement and E_a is the irrigation efficiency that had been measured at the experimental site and could be noted as: 87 and 93 % for sprinkler and drip irrigation systems, respectively.

3. Methods for estimating vegetation covers-water requirements

Vegetation covers (shrubs, trees, and other landscaping) water requirements had been calculated based on the collection and analyzing of micro-climate conditions of the studied area by using weather station and central controller (as a developed technique for scheduling and managing irrigation water), by using the average micro-climate parameters and the calculation based on the designer concepts under the studied area, collected from CLAC for designing and scheduling activities, based on average monthly data (as a common way for scheduling irrigation water). The estimated landscaping vegetation –cover-water requirements were 6-7 mm/day for winter season and 10-11 mm/day for summer season, (IA, 2000b). After then, micro-climatic data had been exposed to the modified Penman-Monteith equation for estimating the vegetation covers-water requirements and irrigation scheduling. Then the operation and management of irrigation systems (landscape sprinkler; surface and subsurface drip irrigation systems) had been considered manual for common way and fully automated for the developed technique.

4. Cost analysis

Cost of operation was calculated according to the equation given by Davies and Richards (2002) in the following form:

$$\text{Costs per year} = \text{Pumping cost} + \text{Labour cost} + \text{Depreciation} + \text{Interest} + \text{Repairs} \qquad (5)$$

where,

Pumping costs, L.E./year = [a] × [b] × [c]
i.e., irrigated area, m^2 [a] × pumping cost, L.E./m^3 [b] × water used, m^3/m^2/year [c]
Labour costs, L.E./year = [h] × [i]
i.e., yearly labour in hours [h] × labour cost in L.E/h [i]
Depreciation, L.E./year = ([d] – [g]) ÷ [f]
i.e., (capital cost, L.E. [d] – resale value, L.E. [g]) ÷ years of working life, year [f]
Average capital value = (capital cost, L.E. [d] + resale value, L.E. [g]) ÷ 2
Interest, L.E./year = average capital value × interest rate [e] ÷ 100
Repairs, L.E./year = yearly repair cost [j]

where,

[a] : Irrigated area landscaping (m^2)
[b] : Pumping cost (L.E./m^3)

[c] : Water use (m^3/m^2/year)
[d] : Capital cost (L.E.), for the present market value of the equipment irrigation system
[e] : Interest rate (%), was taken as the bank-lending rate 7% per year.
[f] : Years of working life expectancy
[g] : Resale value of irrigator, the irrigation equipment would sell for at the end of its working life
[h] : Yearly labour (h)
[i] : Labour cost (L.E./h)
[j] : Yearly repair costs, taken as 5% of its capital cost (L.E./year)

RESULTS AND DISCUSSION

i. Seasonal evapotranspiration under different estimated techniques

Data in Fig. (2) reveal that there is a significant effect due to the application of recent technique (automated irrigation based on application of weather station) either in estimating the actual references evapotranspiration "based on data collected from the located weather station at the studied area", or the actual water requirements of the vegetation cover patterns.

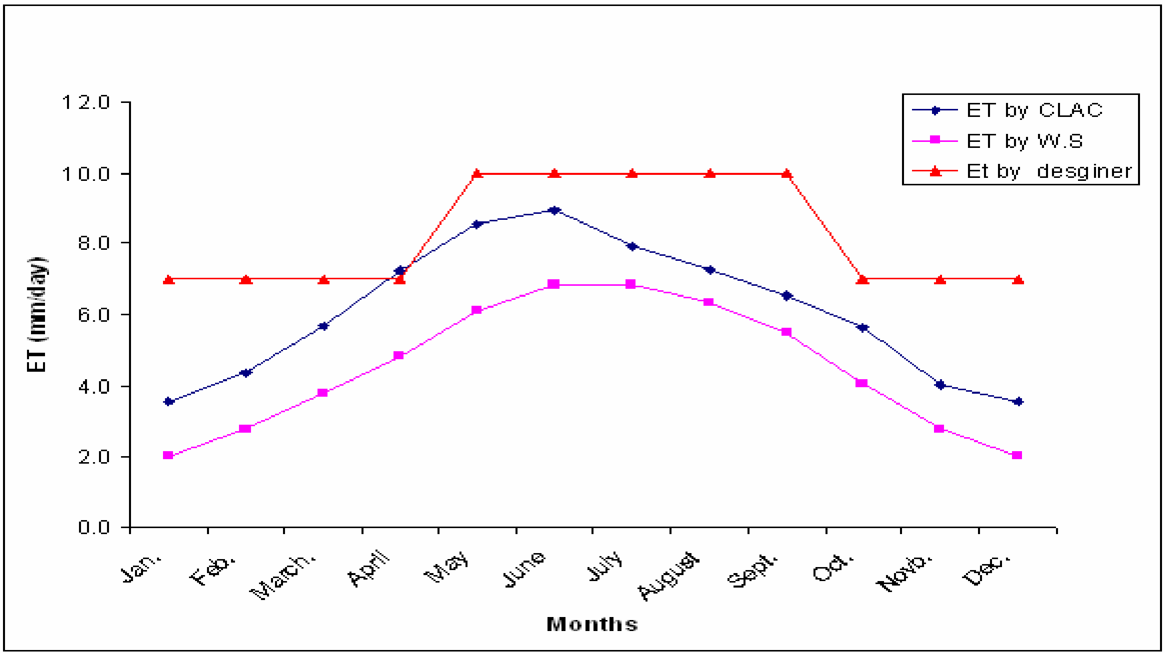

Fig. 2: Effect of different weather station and designer on evapotranspiration

With regard to the estimated reference evapotranspiration, data presented in Fig. 2 indicated that the highest values are obtained by using the fixed scheduling events based on the design concepts and background, followed by the scheduling techniques based on CLAC data. On the other hand, data analysis revealed that water saving fractions had been reached about 0.25, 0.15, 0.167, 0.28, and 0.37 by using the data collected from CLAC over that obtained by using the design concepts. Meanwhile these values were 0.25, 0.39, 0.337, 0.373, and 0.37 by using the fully automated irrigation scheduling technique based on the located weather station. However, these values were estimated from Jan. up to April, April up to May, May up to July, July up to Sept., and Sept. up to Dec. respectively.

The analysis of the earlier data speculated that the highest values of water saving should appear in the winter and spring months over summer. This may be due to the design concepts having highest values of safety during winter months more than summer areas, and this is a logic concept of design thinking to overcome the irrigation network capacity.

ii. Irrigation-water requirements under different irrigation scheduling techniques

Data presented in Figs. (3 and 4) show the effect of irrigation systems (sprinkler and surface drip) on the vegetation cover water requirements among different months of the growing seasons.

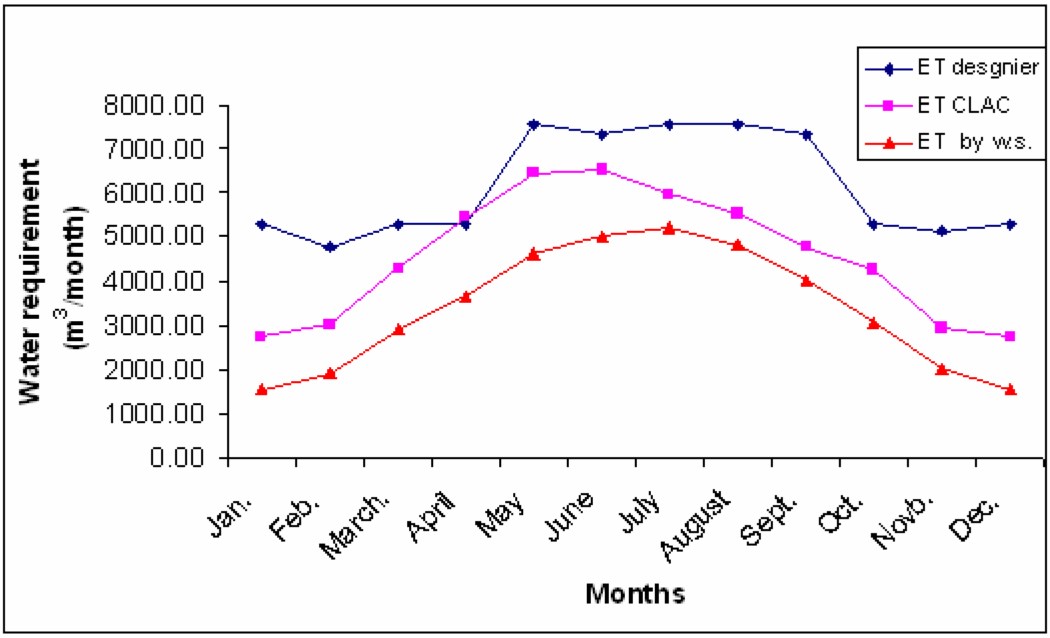

Fig. 3: Effect of different ET locations on water requirement on sprinkler area

Regarding sprinkler irrigation, the highest difference percentage values of the applied irrigation water were 0.43, 0.37 and 0.28 in the time period of Jan. up to Feb.; Oct. up to Dec. and July up to Sept., respectively, when comparing the scheduled irrigation water by using macroclimate data obtained from CLAC and the design concepts . On the other hand, the lowest value was 0.06 in the time period of April up to May.

Concerning the scheduled irrigation based on the data obtained by located weather station at the studied area, data indicated that the highest values were 0.655, 0.58, and 0.45 at months of Jan. up to Feb., Oct. up to Dec. and Feb. up to April. The analysis of the above mentioned results indicated that for applying good irrigation scheduling practices under landscaping turf irrigation, it should be based on the micro-climate data collected from the area of study followed by automatic central control equipment, for saving irrigation water and improving irrigation system effectiveness.

Concerning the irrigation scheduling among different growing months of the vegetation covers during the time of study, data presented in Fig. 4 reveal that same general trends with the drip irrigation had been observed. However, the highest values were 0.43, 0.37 and 0.28 in the time period of Jan. up to Feb.; Oct. up to Dec. and July up to Sept. respectively, when comparing the scheduled irrigation water by using macroclimate data obtained from CLAC and the design concepts. On the other hand, the lowest value was 0.06 in the time period of April up to May. Concerning the scheduled irrigation based on the data obtained by located weather station at the studied area, data indicated that the highest values were 0.66, 0.58, and 0.46 at months of Jan. up to Feb., Oct. up to Dec. and Feb. up to April. So, when scheduling irrigation under landscaping turf irrigation, it should be based on the micro-climate data collected from the area of study followed by automatic central control equipment, for saving irrigation water and improving irrigation system effectiveness.

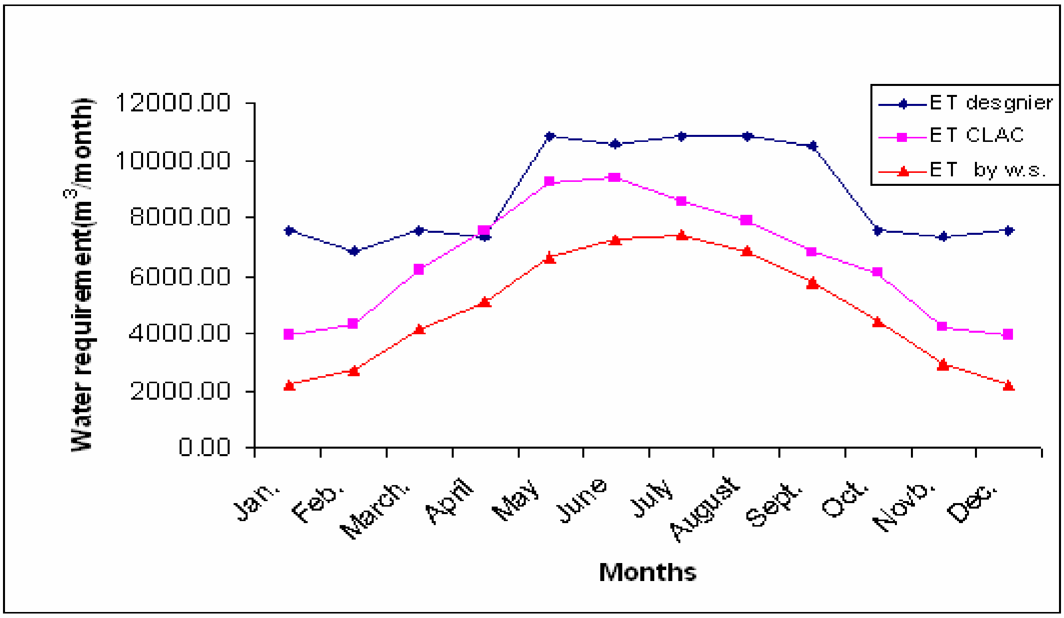

Fig. 4: Effect of different ET locations on water requirement on drip area

iii. Water saving under different irrigation systems and estimated techniques

Data presented in Fig. 5 indicate that the highest values of water saving were under surface drip (with about 0.26) more than under sprinkler irrigation system (with about

0.45) with all different estimated techniques, although the covered area (19525 m^2) under sprinkler irrigation is larger than that under drip irrigation. This may be due to that efficiency of localized irrigation is higher than for sprinkling, thus giving the optimum water saving.

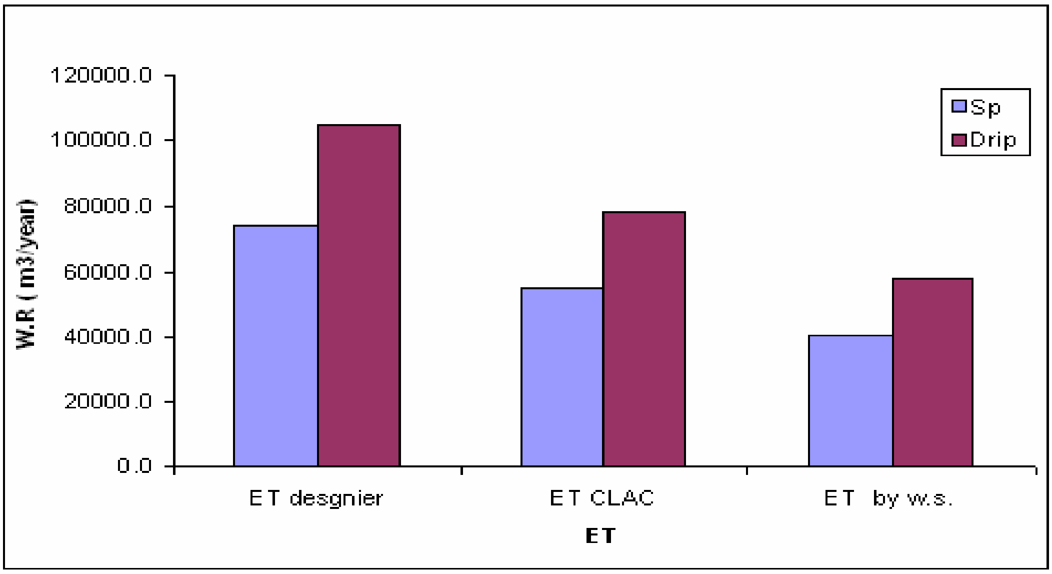

Fig. 5: Effect of different ET locations on water saving

iv. Electrical energy consumption and saving under different turf irrigation scheduling techniques

Data illustrated in Figs. (6 and 7) show the consumed electrical energy for pumping water for the vegetation cover requirements to achieve healthy plants among different months of study. Generally, data analysis revealed that the lowest values of the consumed energy were observed by using automated control of irrigation systems compared with other used techniques (scheduled based on design concepts and CLAC data). These data are in agreement with data of the applied amounts of irrigation water among different months of study. With respect to sprinkler irrigation systems, data revealed that the time of Jan. up to Feb. and Nov. up to Dec. are the highest of consuming energy. This may be due to the error of estimating the reference evapotranspiration based on either design concepts or CLAC data.

On the other hand, data revealed that there is a heterogeneous trend of the consumed energy under drip irrigation systems when using CLAC data technique compared with design concepts. This may be due to the error of estimated ET_o and therefore irrigation scheduling based on the CLAC data technique.

In general, data analysis revealed that the energy requirements and their saving amounts indices appeared to be less under drip irrigation than under sprinkler ones. Although the level of the observed values is not higher than logic summer period is the highest for consuming energy for pumping irrigation water.

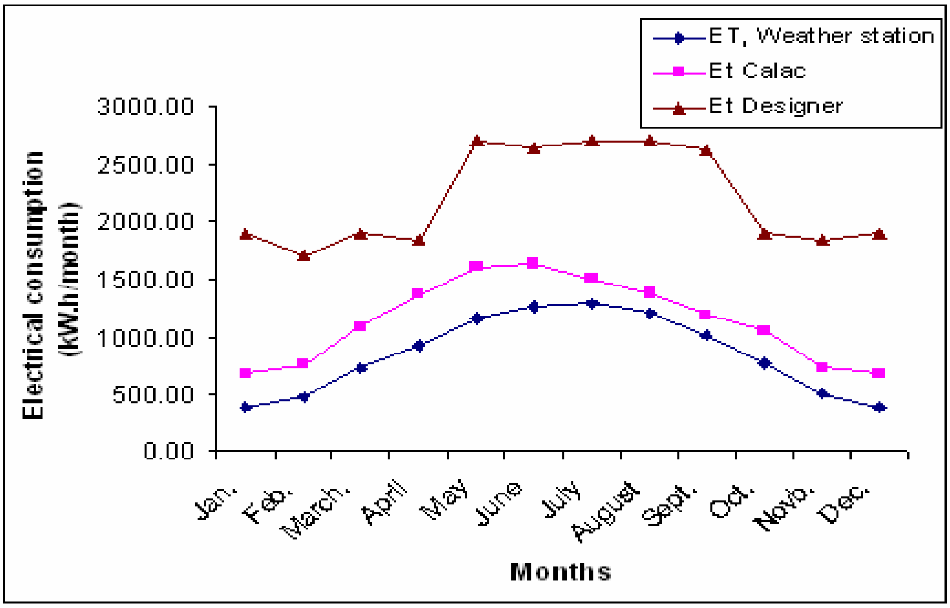

Fig. 6: Effect of different ET locations on electrical consumption for sprinkler area

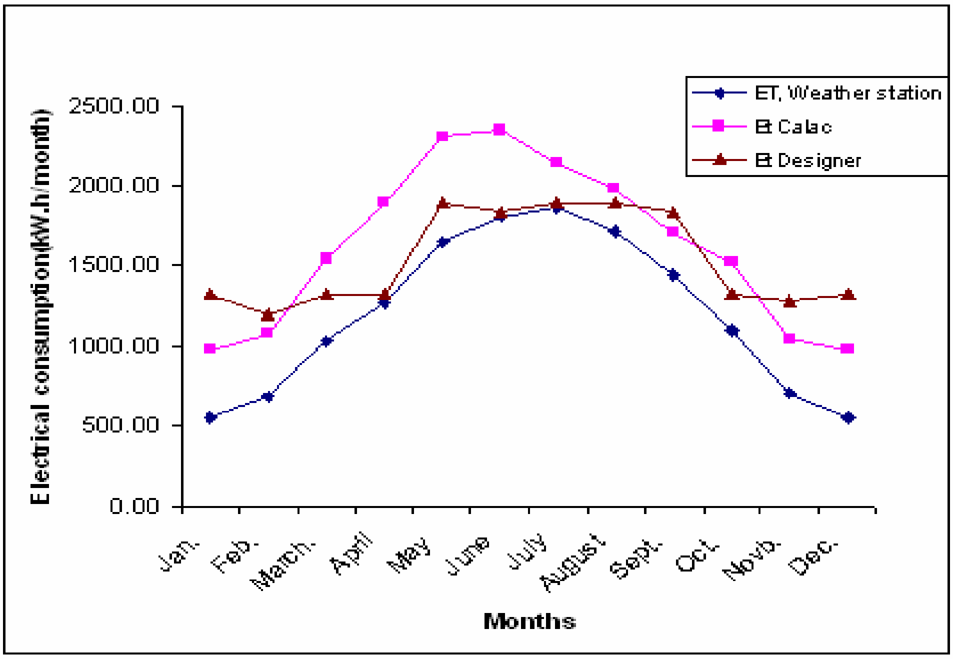

Fig. 7: Effect of different ET locations on electrical consumption for drip area

v. Saving energy

Data illustrated in Fig. 8 indicate that the highest values of electrical saving was under surface drip (with about 0.22) more than that under sprinkler irrigation system (with about 0.62) with all different estimated techniques, although the covered area under sprinkler irrigation is larger than that under drip irrigation. This may be due to water consumptive use under different irrigation systems, thus giving the optimum electrical saving.

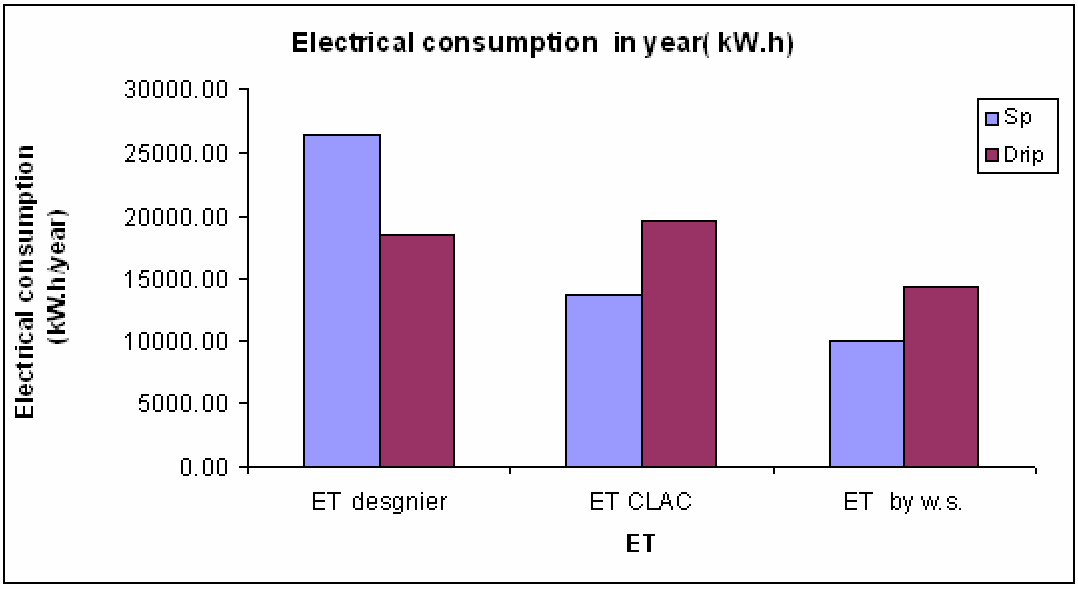

Fig. 8: Effect of different ET locations on electrical consumptive energy

vi. Cost saving

Data presented in Table (4) reveal that the irrigation systems equipped with the recent technique of irrigation water-scheduling get the higher initial costs percentage over the other techniques (scheduling based on design concepts and CLAC data) with about 37.2, 30.1 %, respectively.

Meanwhile, these over costs had saved amounts of water with about 81331, 34725 m^3/year for total area (32000 m^2). On the other hand, data analysis of the total irrigation costs indicated an inverse trend. However, the recent irrigation scheduling technique appeared to be the lowest costs value of about 265232 L.E./year compared with the other investigated techniques.

Table 4 shows the components of the Davies and Richards (2002) equation and total cost of using the designed irrigation landscaping under different investigated techniques.

Table (4): Total cost irrigation landscaping system under different investigated techniques

Item	Et, Designer	Et, CLAC	Et, Weather station
Pumping cost, (L.E./year)	358518.0	265307	195856
Labour cost, (L.E./year)	16425.0	12155	8968
Depreciation cost, (L.E./year)	20526.9	21638	28159
Interest, (L.E./year)	10121.0	10669	13884
Repairs, (L.E./year)	13387.1	14112	18365
Total cost, (L.E./year)	418978.0	323881	265232

CONCLUSIONS

Appropriate irrigation scheduling can be conserved and maintained that avoid plant water stress. To achieve this objective, specific and fine data of soil, plant and climatic parameters could be gathered and analyzed at specific field conditions. Therefore, micro-climatic data had been collected with three scheduling techniques (I_1: based on the design concepts and background; I_2: based on the average monthly microclimatic data observed by CLAC, and I_3: based on the actual instantaneous microclimate data, which had been collected from the located weather station at the experimental site).

The main conclusions of results revealed that scheduling practices based on the actual instantaneous microclimate data based on fully automated turf irrigation systems by using weather station could maximize the irrigation water use efficiency and enhance the irrigation water amount saving by about 43.74 % more than the traditional ways of scheduling, either that based on the design concepts and background or that based on the average values observed by Central Laboratory of Agricultural Climate (CLAC). In addition, data revealed that application of recent scheduling techniques can save about 36.7 % and 62 % of the seasonally operational costs and energy requirements respectively.

REFERENCES

Allen, R.G.; L. S. Pereira; D. Raes and M. Smith, 1998. Crop evapotranspiration: Guidelines for computing crop water requirements - FAO Irrigation and Drainage paper 56, FAO, Rome.

Arafa, Y. E., 2009. Recent approaches for maximizing irrigation water uses and sustainable agricultural development. Congress of Arab Food Security, 17-20 March, El-Khartoum, Sudan.

Attaher, S. M., 2009. Effect of climatic changes of the Egyptian on-Farm irrigation system, Ph.D., Agric. Eng., Faculty of Agric., Ain Shams Univ., Egypt: 45-50.

Awady, M. N.; E. G. Vis; R. Kumar and S. Mitra. 2003. Distribution uniformity from pop-up sprinklers and landscape water-saving. Misr J Ag. Eng. 20(4): 181-194.

Carrow, R. N.; P. Broomhall; R. R. Duncan and C. Waltz. 2002. Turfgrass water conservation. Part I. Primary strategies. Golf Course Manage. 70(5): 49-53.

Castello, L.R; N.P. Matheny and J.R. Clark, 1993. Estimating water requirements of Landscape plantings, the landscape coefficient method, Crop. Ext., U.C. Division of Agriculture and Natural Resources, Leaflet 21493.

Davies, L. and A. Richards, 2002. Costing an irrigation system (net margin calculator), State of New South Wales, Department of Primary Industries Agriculture, Agfact (1st ed.): 112-115.

Irrigation Association (IA), 2000b. Sprinkler system scheduling, The Irr. Assoc.: 153/233.

Irrigation Association (IA), 2005. Landscape irrigation scheduling and water management, p22.

Irrigation Association (IA), 2009. WaterSense Commercial and Institutional Sector Comments, p2.

WUCOLS, 2000. A guide to estimating irrigation water of landscape plantings in California, the landscape coefficient method and WUCOLS III. Cal Coop Ext, Cal Dept. of Water Resource, Bulletins and Reports: 152.

University of California (UC), 2009. Water use curtailment task force, Technical report: 166.