Misr J. Ag. Eng., 31 (3): 885 - 896 IRRIGATION AND DRAINAGE

LANDSCAPE COEFFICIENT TO DETERMINE WATER REQUIREMENT FOR A COMPUTER MODEL

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ABSTRACT

The two factors used to determine landscape water requirement (ET_L), the landscape coefficient and reference evapotranspiration, are solely responsible for producing differences in water loss estimates. For plantings in the same location (i.e., where the same ETo values will be used), the differences will arise solely from the landscape coefficient. To produce useful estimates of water loss, therefore, it is important to carefully determine the value of K_L.

In agriculture, irrigation water requirements are well established for many crops. In urban landscapes, irrigation requirements have been determined for turf grasses, but not for most landscape species. This study adapts this method for application to landscape plantings.

The method used for estimating water needs for landscape plantings is basically the same as that used for crops and turfgrasses. One key change, however, has been made: instead of using the crop coefficient (K_c), a landscape coefficient (K_L) has been substituted.

The main objective of this work is building computer program to determine water requirement for some multi-plant landscape and modern system for their irrigation.

Audit in the accounts of landscape coefficient (K_L) closest to the prevailing conditions by application "Landscape Irrigation Scheduling" program outputs, led to save water use by 60% for landscape plants in Giza (latitude 30° 05', longitude 31°12') with good appearance and growth for landscape plants and grass.

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The program could offer a simple tool for planning ornamental plants and turf grass water requirements for landscape projects.

Keywords**:** Water requirement – Landscape Coefficient – Evapotranspiration – Microclimate – Ornamental plants –Landscape .

INTRODUCTION

Turfgrasses and ornamental plants are considered an integral part of landscape ecological systems worldwide, which provide esthetic value. **(Romero and Dukes, 2009).** Landscape design means choosing the right tree, shrub or flower for a particular place. **(Streich, 2003).**

WUCOLS (2000) and Awady *et al.* (2003) used two formulas to estimate water needs for landscape plantings: • The landscape evapotranspiration formula and,• The landscape coefficient formula. Water needs of landscape plantings (ET_L) can be estimated using the landscape evapotranspiration formula:

$$ET_L = K_L \times ET_o$$

Landscape Evapotranspiration = Landscape Coefficient × Reference Evapotranspiration $K_L = K_s \times K_{mc} \times K_d$

where:

K_L = Landscape coefficient .

K_s = Adjustment factor representing characteristics for a particular plant species.

K_{mc}= Adjustment factor for microclimate influences upon the planting .

K_d = Adjustment factor for plant density (All factor are dimensionless).

Costello *et al.*(1993)

Reference ET (ET_o) is defined as the ET from a 3-6" tall cool season grass that completely covers the ground, and is supplied with adequate water. This turf surface, equivalent to a very tall cool season grass rough on a golf course, is known as the reference crop or reference surface. In the real world, ET_o is not routinely measured, but instead computed from a mathematical formula such as the Penman or Penman-Monteith Equation. Weather data are required for the Penman computation of ET_o. **(Brown, 2000).**

The use of a landscape coefficient (K_L) is a relatively new concept. The advantage of using K_L for landscapes instead of the traditional "crop coefficient" (K_c) is that the K_L value can be adjusted for the microclimate (K_{mc}) and planting density (K_d) impacts upon the plant water requirement as well as for the specific species (K_s). However, K_L cannot be used if its K_s factor is unknown. In some regions of the country, only information on K_c may be available. **(IA.2005)**

MATERIALS AND METHODS

Landscape Irrigation Scheduling program (LIS).

Landscape Irrigation Scheduling program (LIS) flow chart (Fig.1).

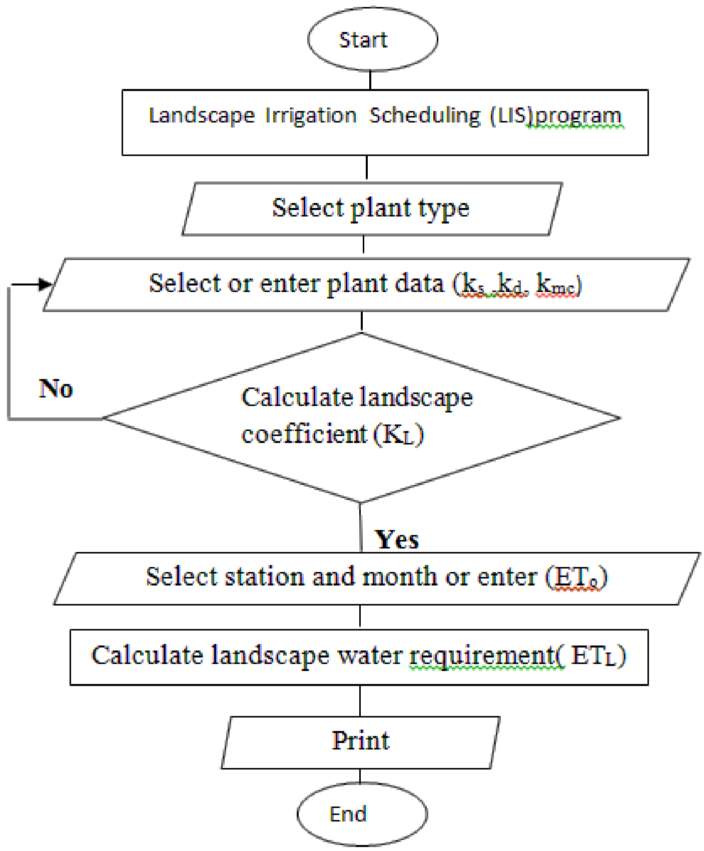

Fig. 1. Flow chart components of the" Landscape Irrigation Scheduling "(LIS)" program.

This program is set up for this work. Its input are as follows:

To register the program, enter user name and password, and click login.

1. Plant Type.

The vegetation type is selected because decision must be made on the factors of vegetation water use, vegetation density and area microclimate. You can search the plant name to know the plant of any category (Fig.2).

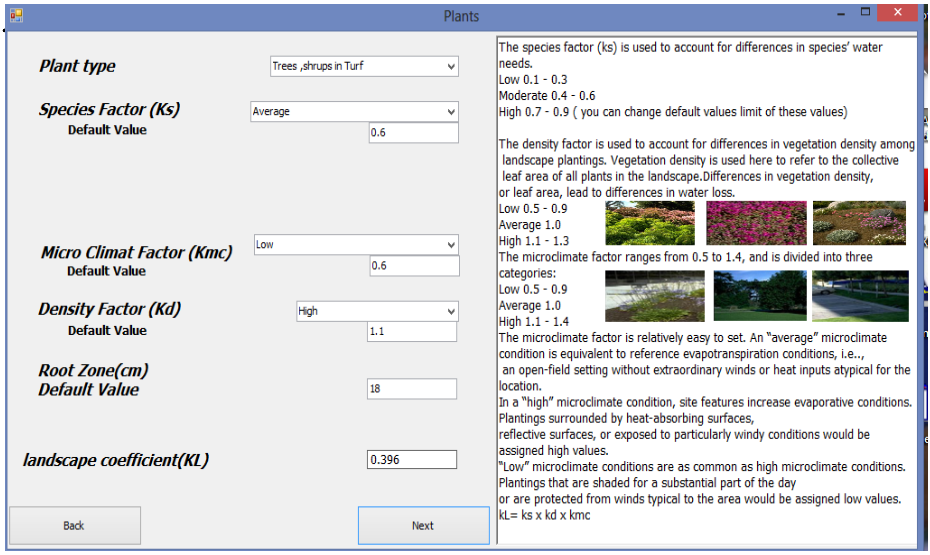

Fig.2.Plant type.

2. Evapotranspiration (ET).

LIS program is based on historical ET_o. One can irrigate fairly accurately using historic ET_o data, Thus, ET_o information is available as historical data from "Central Laboratory for Agricultural Climate". These values of ET_o can be changed if desired and entered (Fig.3).

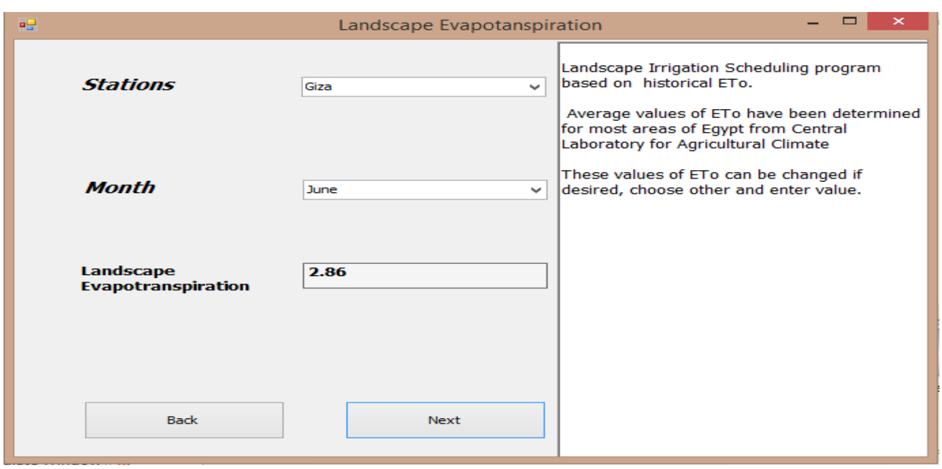

Fig.3.Landscape evapotranspiration.

3. Landscape water requirement.

The landscape water use (ET_L) can be calculated for a specific plant by using a reference evapotranspiration rate (ET_o), and applying a landscape coefficient (K_L) to convert the reported ET_o to ET_L.

A site audit was conducted on the study area with the results shown in the table 1.

Table 1: Site audit conducted on the study area.

No.	Cases Attribute	Case1	Case2	Case3
1	Landscape area (A)(m^2)	54	90	14
2	Irrigation system	Fixed Spray Head	Fixed Spray Head	Drip in line (Bed area)
3	Precipitation rate (PR)mm./h.	96.17	65.39	16
4	lower-quarter distribution uniformity (DU_{LQ})%Emission uniformity(EU)%	45.9	40.2	91.5
5	Soil Type	Clay	Clay	Sandy
6	Plant Type	Trees and shrubs in turf	Trees and new shrubs in new turf	Mixture (Sedum spp.and new shrubs)
7	Root Zone Depth(cm)	18	15	15
8	Plant Ks	Average	Average	Average
9	Microclimate	Full shade (south side of office building)	Full shade (south side of office building)	Full shade (south side of office building)
10	Density	High	Average	Low

RESULTS AND DISCUSSION

1. Average daily historical reference evapotranspiration.

The historical reference ET (ET_o) for the irrigation season (Jan. through Dec.) is provided in table 2. These values are the for experiment only.

Table 2: Average daily historical reference evapotranspiration.

Average daily histori*cal*	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Reference ETo (mm/day.)	2.2	2.7	4	5.14	6.43	7.21	6.8	6.12	5.5	4.54	3.27	2.2

2. Landscape coefficient (K_L).

Case1: comprised a mature planting of Dodonaea, Acalypha, Lantana camara and star jasmine in an amusement park in Doki. The planting is full, but shaded in the afternoon by an adjacent building. The building also blocks afternoon winds as typical for the area.

$k_s = 0.6$ $k_d = 1.1$ $k_{mc} = 0.6$

$$K_L = 0.6 \text{ x } 1.1 \text{ x } 0.6 = 0.396$$

Analysis: Species in this planting are in two different WUCOLS (Water Use Classification of Landscape Species) categories: low (Dodonaea ,Bougainvilla and Lantana camara), moderate (Star jasmine, Acalypha). To maintain the warm season turfgrass in good condition, a k_s value of 0.6 is needed. This means, however, that both the Dodonaea ,Bougainvilla and Lantana camara will receive more water than they need. Obviously this is not a water-efficient planting. Since the canopy cover is 100% and all two vegetation types occur, this is a high density planting and a k_d of 1.1 is assigned. Since the building shades the planting and protects it from wind, the microclimatic factor is low and a k_{mc} value of 0.6 is assigned.

Case2: comprised new planting of Duranta repens and Hibiscus rosa-sinensis,. All plants were in a 1-liter plastic container, placed in shade by an adjacent building. Canopy cover was 20 to 30% but planting was in turf .Water supplied to meet turf needs was often not sufficient for new plants in turf. However, turf irrigation was likely to be sufficient for most species once established,

$k_s = 0.6$ $k_d = 1.0$ $k_{mc} = 0.6$

$$K_L = 0.5 \text{ x } 1.0 \text{ x } 0.5 = 0.25$$

Analysis: All species in this planting are classified as moderate in the WUCOLS list with a midrange value. To maintain the warm season turfgrass in good condition, a k_s value of 0.6 was needed. Since this is a new planting and canopy cover is not full, it was placed in an average density category and assigned a k_d value of 1.0. The micro climate factor is low and assigned a value of 0.6.

Case3: A new planting of Echinocactusgrusnii, Sedum spp. and Durantarepens were considered. All plants were in a 1-liter plastic container, planted in shade by an adjacent building. Canopy cover was 10 to 20%.

k_s= 0.5 k_d = 0.5 k_{mc} = 0.6

$$K_L = 0.5 \text{ x } 0.5 \text{ x } 0.5 = 0.15$$

Analysis: Species in this planting were in two different WUCOLS categories: low (Echinocactusgrusnii, Sedum spp.), moderate (Durantarepens). To maintain the Durantarepens in good condition, a k_s value of 0.5 is needed. Since this was a new planting and canopy cover is not full, it is placed in a low-density category and assigned a k_d value of 0.5. The microclimate factor was low and assigned a value of 0.6.

These field examples should provide an understanding of how values for each of the landscape coefficient factors are assigned and used. In addition, an appreciation for the diversity of species, differences in vegetation density, and variation in microclimates which exist in landscapes should be realized. In many cases, there will be a different landscape coefficient for each irrigation zone.

3. Average daily plant water requirement.

Table 3 shows the average daily plant water requirement of each month of the experiment. Cases were base on the data for input to "LIS" program.

These calculations show that landscape irrigation water needs vary substantially. Estimates range from 1.08 mm/day to 2.86 mm/day for the month of July will more than a 2.5-fold difference in this experiment only.

Table 3: Average daily plant water requirement.

Daily	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
ET_L.daily (mm.) Case1	0.87	1.07	1.58	2.04	2.55	2.86	2.69	2.44	2.18	1.98	1.30	0.87
ET_L.daily (mm.) Case2	0.79	0.97	1.44	1.85	2.32	2.60	2.45	2.20	1.98	1.63	1.18	0.79
ET_L.daily (mm.) Case3	0.33	0.40	0.06	0.77	0.96	1.08	1.02	0.92	0.83	0.68	0.49	0.33

4. Plant growth measurements.

The growth index was determined in July to Dec. 2013 for (Dodonaea ,Acalyphagodseffiana, Lantana camara, ,Jasminum and Bougainvilla) as shrubs. The percentages of increase in the height of plants (shrubs) in July to Dec. 2013 were 51.08, 59.69, 41.96, 33.89, and 23.64% for (Dodonaea. Acalyphagodseffiana, Lantana camara, ,Jasminum and Bougainvilla) resp. (Fig. 4).

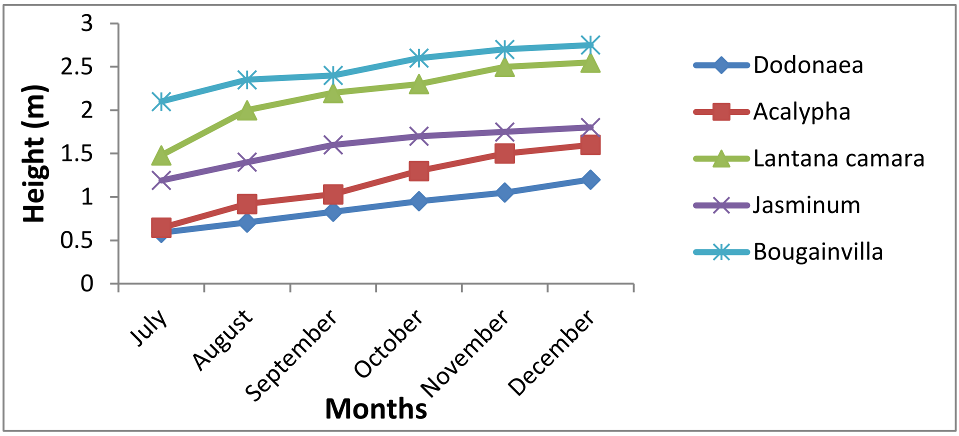

Fig. 4.Height (m.)determined in July to Dec.2013 for different plants.

The percentages of increase in the canopy area (m^2) of plants (shrubs) in July to Dec. 2013 were 55.17, 62.1, 49.28, 48.75, and 35.14% for (Dodonaea ,Acalyphagodseffiana, Lantana camara, ,Jasminum and Bougainvilla) respectively (Fig. 5)

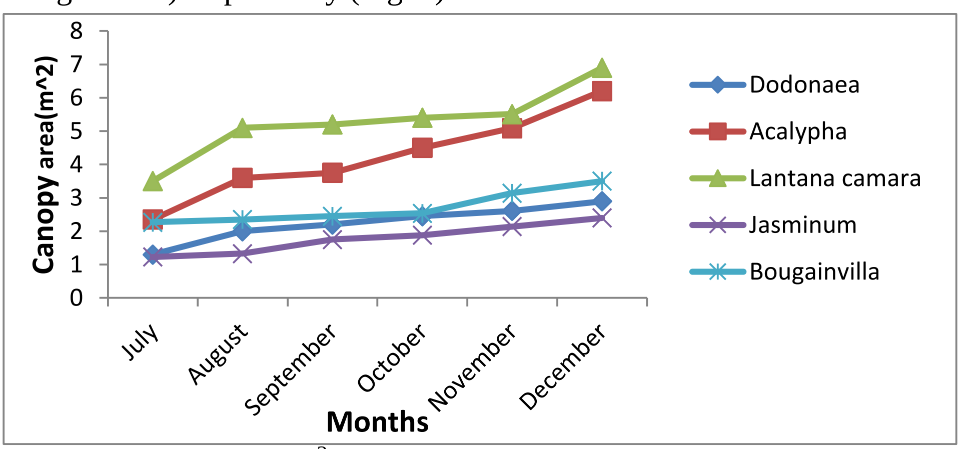

Fig. 5.Canopy area (m^2) determined in July to Dec. 2013 for different plants canopy surface area [width × width (square meters)].

The percentages of increase in growth index of plants (shrubs) in July to Dec. 2013 were 78.07, 84.72, 84.19, 66.12, and 50.47 % for (Dodonaea ,Acalyphagodseffiana, Lantana camara, ,Jasminum and Bougainvilla) respectively (Fig.6).

Canopy dimensions were multiplied to calculate a growth index [GI = width 1 × width 2 × height (cubic meters)], to estimate canopy volume.

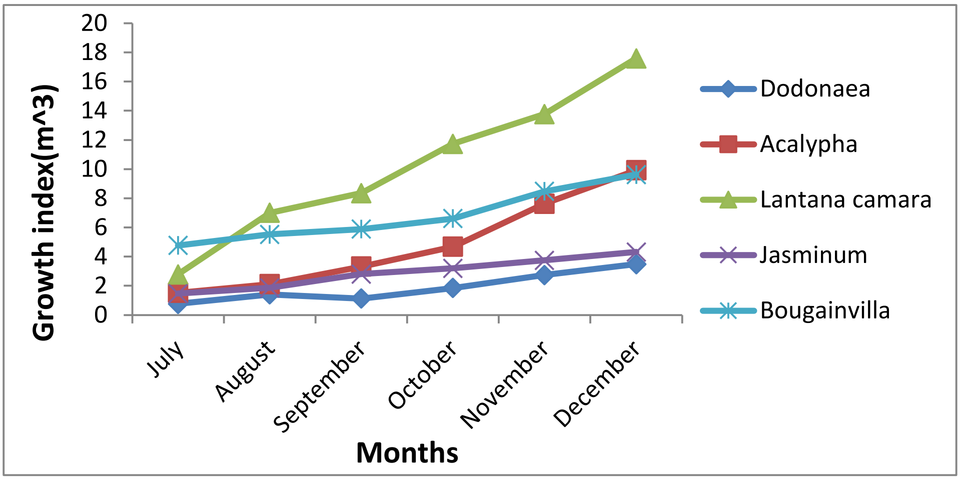

Fig. 6. Growth index (m^3) determined in July to Dec.2013 for different plants growth- index [GI = width 1 × width 2 × height (cubic meters)].

5. Estimation of water use.

Due to the differences in plant size and leaf area, water use of plants was expressed in daily water use per case. Fig.7. indicate water use per case and compares with water use for reviews that do not use landscape coefficient, and use crop coefficient for landscape equal one and water use of plants 100% reference ET_o . Therefore, landscape coefficient (K_L) of plants varies not only by plant species, but also by leaf area, growth rate and/or density factor. Without quantifying plant size, although microclimate is similar for the three cases.

The average daily plant water requirement when using 100% reference ET_o compared with landscape coefficient to estimate average daily plant water requirement for each case were 60, 64 and 85 % for (case1 ,case2 and case3) respectively (Fig.7).

Quality plant material is important in a successful evaluating implementation. Having good mental images of the growth habit and form native plant species have in their natural habitats will help in the evaluation process.

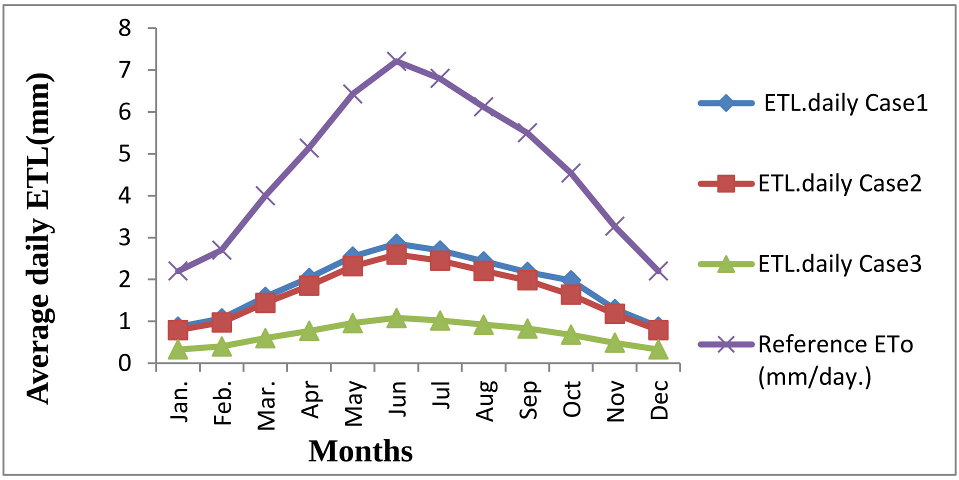

Fig. 7. Average daily plant water requirement (mm./day) monthly compared with reference ET_o(mm./day).

CONCLUSIONS

This research provides an understanding of how values for each of the landscape coefficient factors are assigned and used. In addition, an appreciation for the diversity of species, differences in vegetation density, and variation in microclimates exists in landscapes. In many cases, there will be a different landscape coefficient for each irrigation zone.

The study recommends using "LIS" Program to determine the species factor K_s of plants under consideration with the knowledge of other microclimate, and density factors. A guide for ornamental plants to calculate landscape coefficient and landscape evapotranspiration (ET_L) is recommended. The "LIS" Program succeeded because it saved water, proved to be cost-effective. The results of this study will not only serve water specialist to estimate landscape requirement, but also help horticulture planner to choose plants having similar water use together on the same region.

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الملخص العربى

إستخدام معامل البستان لتحديد الأحتياجات المائية باستخدام الحاسب الآلي

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يتناول البحث دراسة العوامل المؤثرة على الاستهلاك المائي لبعض نباتات الزينة باستخدام برنامج حاسوبي مع تنوع نباتات الزينة و التى تختلف احتياجاتها من نبات إلى أخر .فهناك الأنواع النجيلية ،والشجيرات ،والأشجار ،وكلها في نفس المكان ،مما يتطلب مراعاة كل ذلك في تخطيط وتصميم نظام الري اللازم ، وخصوصاَ أنه يتوقف على تركيبة النباتات وكثافتها ،والعوامل المناخية شاملة العوامل المناخية الصغرى (microclimate) ويعد استخدام هذه العوامل من المفاهيم الجديدة لحساب الاحتياج المائى لنباتات الزينة.

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لذلك فإن تقدير أو قياس الاحتياجات المائية لنباتات الزينة يعد من الأمور الأساسية الواجب توفرها . خاصة عندما تكون مصادر المياه محدودة، ويساعد تقديرها ايضًا في اختيار أنواع النباتات الملائمة للزراعة.

تتلخص أهم مخرجات البرنامج في:

تحديد الاحتياجات المائية لكل نبات باستخدام المفهوم الجديد وهو معامل البستان (K_L) والعوامل المؤثرة فى تلك المعامل وهى :-

-معامل نوع النبات المستخدم (K_s)،

- معامل كثافة الزراعة (K_d)،

- معامل العوامل المناخية الصغرى (K_{mc}).

وقد أجريت التجارب الحقلية الخاصة بتطبيق البرنامج فى حديقة معهد بحوث الهندسة الزراعية بالدقى - الجيزة (دائرة عرض 30° 05' - خط طول 31° 12') . استخدم في الدراسة ثلاثة أحواض مختلفة من نباتات الزينة :الأول والثانى خلط بين انواع مختلفة من نباتات الزينة ونجيلة بكثافة مختلفة بين الحوضين تم ريهما برشاشات رذاذ والحوض الثالث انواع مختلفة من الصبارات بالاضافة الى شجيرات بكثافة منخفضة وتم ريها بنقاطات داخلية تصرف ٤ لتر /س ،وتم تطبيق مخرجات البرنامج بعد ادخال بيانات كل حوض.وجد ان التدقيق فى حسابات معامل بساتين الزينة الأقرب للظروف السائدة أدى الى وفر فى إستخدام المياة بنسبة ٦٠% عماكان يستخدم عند رى هذة النباتات (K_c=1) اى ١٠٠% من البخر نتح المرجعى طبقا للمراجع السابقة دون ان يظهر ذلك اى تأثير على النبات من حيث النمو ومظهر الشكل الخارجى ، بالاضافة لعدم تأثر لون النجيل المزروع بالحوض الأول والثانى حتى فى فصل الشتاء الذى يتأثر فيه النجيل بشكل كبير باستشارة متخصصي ري بساتين الزينة المترددين على أحوض الزراعة مما يعكس أهمية استخدام معامل البستان (K_L) فى تحديد مخرجات البرنامج .