Canal de Isabel II

BOOKLETS

Research + Development & Innovation

10

Water use efficiency in gardening in the region of the Comunidad Autónoma de Madrid

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Introduction

Canal de Isabel II's Research, Development & Innovation Booklets form part of the company's Knowledge Management Strategy and of the development involved in the Research, Development and Innovation Plan.

These Booklets represent an element for diffusion of projects and initiatives that are developed and sponsored by Canal de Isabel II for innovation in those areas related with water service in the urban environment.

A series of different problems that have been undertaken in each project are put forward in the Booklets, along with the results that have been obtained. The intention behind their diffusion by means of these publications is to share the experiences and knowledge that has been acquired with the entire water services sector, with the scientific community and with all those working on investigation and innovation tasks. What is aimed with the publication of these Booklets is to contribute to improvement and efficiency in water management and, consequently, in the quality of service that is provided to the citizens.

The R&D&I booklets published to date are as shown below by their titles in the following table.

Collection Number	Research, Development and Innovation Booklets published
1	Transferences of Water Rights between Urban and Agrarian Demands. The case of the Community of Madrid
2	Identification of Hydrometeorological Runs and Tendencies within the scope of the Canal de Isabel II system
3	Contribution of Canal de Isabel II to the International Demand Management Project (IDMF)
4	Micro-components and Explanatory Factors on Domestic Water Consumption in the Comunidad de Madrid
5	Virtual Water and Hydrological footprint in the Comunidad de Madrid
6	Study on the saving potential of water for residential uses in the Comunidad de Madrid
7	Potentials of efficiency in using dishwashers
8	Accuracy in the measurement of individual water consumption in the Madrid Region
9	Research project to define and assess the applicability of a Bioassay Test to determine the toxicity of water using Zebra Fish embryos

Project Outline

Project title	Water Use Efficiency in Gardening in the Region of Comunidad Autónoma de Madrid
Research line	Guaranteeing a balance between availabilities and demands
Canal de Isabel II units involved	• R&D&I Deputy Direction • Green Areas Division
External participation	• TALHER • Jardinería José Luis Vilar Arias
Aim and justification of the project	Establishing the potential for improving irrigation efficiency in green zones, quantifying and comparing water needs and the costs of the different plantation options, irrigation systems and garden operation and maintenance systems.
State of the art contribution	The water requirements are established for the plants whose use is most widespread in the Autonomous Region, by ongoing measurement of the climate and moisture content of the ground, plus discrete measurements of the health and aesthetic state of the plantations. The water use efficiency results and the cost of the options studied are established by means of a cost-efficiency ratio.
Project development summary and milestones	• Setting 60 experimental plots in the Pilot Park, each one containing different plant combinations, irrigation systems and gardening techniques. • Adjusting and calibrating the moisture gauges and starting to conduct the tests. • Developing and calibrating the irrigation allocation methodology. • Experimenting with the plots and calculating how efficiently the different options use water. • Final report.
Obtained results summary	• An assessment was made of the water use efficiency of the plants which are most extensively used, in gardening in the Comunidad de Madrid, of the irrigation systems, and of the main techniques applied in gardening. • The cost involved in selecting each option was calculated, including the cost of implementation, maintenance and the water invoice for an estimated service life of 10 years. • A methodology has been developed for calculating the regulated deficit irrigation allocations based on the climate through the ongoing measurement of the moisture content in the soil.
Research lines open for continuing the work	• Appraisal of the impact of the watering recommendations campaign “Today there’s no need to water”, by monitoring the Pilot Park. • Establishing the minimum watering levels that conserve the aesthetic state of the landscape, or controlled deficit irrigation, for each growth stage by using the information about the ground and the climate and incorporating physiological parameters. • Modelling an expert plant system. • Developing tools and practices for improving the advanced service of the SIR (Intelligent Irrigation System).

Executive Summary

This document contains the results and conclusions obtained from a study that was conducted for 18 months at an experimental pilot park. The main aim of this study was to assess compared water consumption and the cost-efficiency of the different options of plants that are available when designing a garden with a view to improving efficiency in the use of water in gardening in the Autonomous Region of Madrid. This efficiency is inversely proportional to the consumption of the resources, water and labour charges that are needed to provide parks and gardens with the required welfare and aesthetic quality.

As is the case with any other green zone, watering in the experimental pilot park provides the plants and soil, in which their roots take hold, with the resources to meet the evapotranspiration requirements caused by the climate.

The potential evapotranspiration of the benchmark crop, **ETo**, is the parameter generally used to assess the evaporation and transpiration requirements generated by the climate. The **ETo** depends exclusively on the climate and is defined as the amount of water that evaporates, under those climatic conditions, from land covered totally by gramineae (grasses) or alfalfa (used as reference crops) ranging from 8 to 15 centimetres high and uniform, under active growth conditions and not affected by a water shortage. Several formulae can be used to calculate it, but always on the basis of climate parameters.

The plants take water from the ground, so the amount of water stored in the ground and available to the plant establishes whether or not the plant can meet its needs. Every plant species has certain mechanisms for developing its basic functions and for growing, so every crop or plant (together with the ground in which it grows) uses a different amount of water, **ETc**, evapotranspiration of the crop concerned. The relationship between the latter and the benchmark crop is represented using what is referred to as the crop water-use efficiency coefficient, **Kc**, (**Kc** = **ETc** / **ETo**), nearly always less than one unit. Furthermore, each plant consumes different quantities of water depending on its current growth stage; as a result, **Kc** is not constant in time. Finally, plants are, to a greater or lesser extent, able to adapt their development process and consumption strategies to the water available in the ground.

Concisely, watering or irrigation decisions will depend on the climate conditions, the plant and the ground. The climate brings about the need (and when it rains it provides the resources), the species and its current growth stage determine the consumption strategy, while the ground stores the water reserves with which the plant will obtain its supplies. The way in which the water stored in the ground evolves, reflects the balance between the irrigation and the consumption, showing whether the irrigation meets requirements, or if it is excessive or deficient.

Furthermore, the irrigation allocation must include the water that does not reach the soil stratum that is reached by the roots, either because it evaporates, runs off the surface or seeps down too deeply. This is calculated by using an irrigation system efficiency coefficient, **Kr**, which increases the proportion of water concerned.

Certain gardening operation and maintenance techniques also affect the evaporation through the ground and/or the plant transpiration process. This effect is expressed as a gardening technique coefficient, **Kt**.

Irrigation allocations can be calculated, on the basis of the climate measured, using the following formula:

$$N_R = ETo \times Kc \times 1/Kr \times Kt,$$

Where N_R represents the irrigation requirements

When comparing the water-use efficiency of the different options with a view to recommending the irrigation allocations, thus calculated for parks and gardens, where there is no information about the moisture content of the soil, it is necessary to evaluate the efficiency coefficients for the plant, the watering system and the gardening technique, so that it will be possible to calculate the watering requirements, on the basis of the climate, using the above formula, which conceptually is very similar to the Costello Method for calculating irrigation allocations. This indirect method is the most extensively utilised, and it is used to calculate the irrigation allocations from the climate data (**ETo**) over the last few days, plus the crop coefficients and the irrigation system coefficients, as well as taking into account other local peculiarities of the garden to be watered, such as density, shade, the microclimate and other factors.

A methodology combining an indirect plus a direct method was used in this project. Where the indirect methods are concerned, the irrigation allocation is calculated using the climate parameter measurements and plant efficiency coefficients, watering system and gardening technique, which transform the benchmark-crop evapotranspiration requirements under these climate conditions, into the irrigation allocations that each green zone needs. Direct methods monitor parameters inherent to the plant itself, as well as the ground in which its roots have taken hold. Direct methods provide certainty and precision, but it is easier and more economical to apply indirect methods. A direct method was initially used in the project to calculate the efficiency coefficients. Once they had been calculated, an indirect method was utilised to establish the irrigation allocations. The results yielded by applying this indirect method were periodically assessed by analysing the direct methods and recalibrating the efficiency coefficients.

The irrigation allocations using the direct method were calculated by combining the use of ongoing climate parameters, with direct measurements of the soil moisture content taken continuously, and of the plants' landscape or ornamental state, on a weekly basis.

All in all, an eclectic method was developed that is halfway between the indirect method, depending on the theoretical-experimental parameters, and the direct method, using measurements taken in the park or garden, both from the plant and the water available in the ground.

The resources used for this work were a 4,000 m^2 pilot park split into 60 experimental plots, where the different combinations selected as the study variables were tested: plant type, watering system and gardening technique. Traditional options and other more innovative proposals were studied. Each plot was equipped with a moisture gauge that was permanently measuring the water reserves in the ground, as well as an individual meter and an electrically-operated valve.

The information concerning the climate parameters in the pilot park was taken and compiled by a fully-equipped meteorological station.

The testing process was monitored by sending all the data taken by the sensors, via radio, to a computer that managed the information not only from the meteorological station but also from the moisture gauges and meters installed in each plot. The information was processed, and a series of irrigation allocations were calculated and were applied using irrigation programmers.

When designing the test plots, a different combination of the variable being studied were planted and/or installed in each one of the 60 plots: plant species, irrigation system and gardening technique. Certain repetitions were included in order to control unidentified variables.

When the experiments were initiated, the irrigation allocations were estimated using coefficients from the reference works. As the project progressed these allocations were adjusted by monitoring the ground moisture in each plot, in an attempt to ensure that the moisture converged towards an objective range.

Figure 1. General view of the Pilot Park

The way the water reserves evolved is a consequence of the balance between the requirements (the climate) and the inflows (the irrigation). Therefore, an awareness of how the climate and the ground moisture content evolved, enabled those responsible to adapt the irrigation so that the moisture content remained within an objective range of useful water, in which the ornamental state of the plants was sufficient, minimising the growth development to cut down on water consumption; this is known as **controlled deficient irrigation**. Useful water refers to the resources that the plant is able to use; the upper limit lies in the ground storage capacity or the maximum amount of water that the ground can store; whereas the lower limit or wilting point is the moisture that a given plant can absorb from a particular soil; below that point the plant wilts and dies.

The **Gardener's Index** was used to check that the objective moisture interval of useful water for each plot was correct, i.e., that it achieved a suitable ornamental state; this Index, which requires a specialized visual control over the aesthetic state of the plants, uses a rating system ranging from 1 to 5, where 3 means that the objective aesthetic appearance of the plant is optimum, 1 indicates excessive water stress, and 5 indicates excessive moisture.

Ongoing climate and ground parameters were monitored with this methodology, checks being made periodically to examine the aesthetic appearance of the plants. The plant parameter based upon a visual and subjective assessment of the plant's condition, expressed in terms of the Gardener's Index, limited the obtaining of an exact and dynamic adjustment of the Kc on the basis of the plant's current growth stage.

It has been, not only, demonstrated that direct methods can be applied for the purpose of calculating efficient irrigation allocations, but also that it is feasible to extrapolate the efficiency so that indirect methods can be used.

RESULTS

As a result of the work, efficiency coefficients were obtained not only for the different irrigation systems used, but also for the gardening techniques.

These coefficients can be seen in tables 1 and 2.

Table 1. Irrigation system efficiency

Irrigation System	Efficiency
Sprinkle	0.75
Diffuser	0.75
Bubbler	0.85
RWS	0.95
Drip	0.9
Underground drip	0.95
T-Tape	0.90
Manual with hose	0.95

Table 2. Gardening technique efficiency

Gardening Technique	Coefficient
Recycler and cropping height	0.80
Splitting irrigation	0.95
Mycorhyzaes	0.80
Retainer	0.80
Mulching 1: Geotextile + Pine Bark	0.80
Mulching 2: Geotextile + Gravel	0.75
Mulching 3: Geotextile + Gravel + Pine Bark	0.70

Values were also obtained for the efficiency coefficients of the crops that were tested.

An evaluation of the water-use efficiency of the variables studied, expressed by the coefficients, would enable to calculate the water consumption of each option and the water-saving potential, if one has knowledge about the climate and the inventory of plant species in the parks and gardens in a municipality or region.

The cost of implementing, maintaining and consumption of water irrigation has also been calculated for a 10-year period. The data obtained have been used to establish a cost-efficiency ratio that combines economic and water-use efficiency criteria, which also enables us to compare the different options, providing rigorous information that can be used for decision-making purposes.

The efficiency and cost results, together with the ratio that integrates the two parameters, are shown below for some of the options.

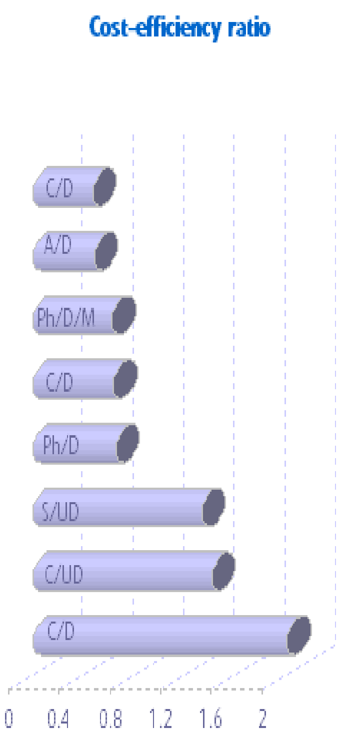
Table 3. **Plant efficiency**

Crop	Kc Value
Lawn (HWR) – Classic	0.70
Lawn (LWR) – Sahara	0.65
Tree – London Plane	0.50
Large shrub (HWR) – Photinea	0.4
Large shrub (LWR) – Cornus	0.35
Hedge (HWR) – Privet	0.60
Hedge (LWR) – Leyland Cypress	0.60
Small shrub (HWR) – Hebe	0.50
Small shrub (LWR) – Atriplex	0.25
Ground cover plant (HWR) – Periwinkle	0.45
Ground cover plant (LWR) – Creeping Rosemary	0.25
Ground cover plant (LWR) – Thyme	0.40
Ground cover plant (LWR) – Hypericum	0.30
Flower (HWR) – African Marigold	0.55
Flower (LWR) – Petunia	0.55

HWR: High Water Requirements; LWR: Low Water Requirements

Table 4. **Cost-Efficiency Ratio**

Crop/Irrigation/ Gardening Technic option	Water saving when compared to *Classic Lawn* with Diffuser %	Total cost in 10 years €/m²	Ratio Coste-Eficiencia (base log)
Cotoneaster/Drip	70.23%	31.59	0.47
Atriplex/Drip	70.23%	32.13	0.48
Photinea/Drip/Mulching	66.67%	42.66	0.62
Cotoneaster/Diffuser	64.29%	42.23	0.63
Photinea/Drip	52.38%	36.65	0.65
Sahara/Underground Dip	26.69%	100.71	1.33
Classic/Underground Dip	21.05%	101.82	1.41
Classic/Diffuser	0.00%	107.69	2.04



The results obtained show that the most efficient water-use options are also the most economical in the service life of the plantations and watering systems; this is because the cost of the water that is saved by far outweighs the greater initial investment costs that are sometimes required for the most efficient options. This relationship between efficiency and cost is further endorsed by the fact that the greater plant growths resulting from the intensive use of water also involve greater expenditure for maintenance purposes.

The conclusion has been reached that a 70% saving of irrigation water achieved by changing the crops, watering system and gardening techniques, does not amount to any additional cost, quite the contrary, it brings about a saving of two-thirds when one takes into account both the total cost during the life cycle of the plants and the cost of the watering structures.

The table 5 shows the annual volume of unconsumed water for one hectare of green zone with the characteristics of some of the options studied, showing how this compares to the consumption in a conventional lawn.

Table 5. Cost, efficiency increase and volume saved

Crop/Watering/Gardening Technique Option	Water saving when compared to *Classic Lawn* with Diffuser %	Water saving when compared to *Classic Lawn* with Diffuser m^3/ha/year	Total cost in 10 years €/m^2
Classic/Diffuser	0%	0	107.69 €
Classic/Diffuser/Splitting Irrigation	5%	421	106.68 €
Classic/Diffuser/Cropping height	20%	1,683	103.65 €
Classic/Diffuser/Mycorhyzae	20%	1,683	104.10 €
Classic/Underground drip	21%	1,772	101.82 €
Sahara/Underground drip	27%	2,247	100.71 €
Sahara/Diffuser	7%	601	106.28 €
Periwinkle/Diffuser	36%	3,006	46.15 €
Periwinkle/Drip	46%	3,908	34.56 €
Petunia/Diffuser	21%	1,804	306.34 €
Cotoneaster/Drip	70%	5,912	31.59 €
Hebe/Drip	40%	3,407	33.41 €
Photinia/Drip	52%	4,409	36.65 €
Photinia/Drip/Gravel/Geotextile	62%	5,210	44.49 €
Photinia/Drip/Pine Bark/Arena	67%	5,611	42.66 €
Atriplex/Bubbling	68%	5,764	45.46 €
Atriplex/Drip	70%	5,912	32.13 €

The improvements that can be achieved in water-use efficiency range from 60 to 70%, if lawns irrigated by sprinkling or spraying are replaced with shrubs that have average and low water requirements, irrigated with local watering systems, with the ground covered by mulching.

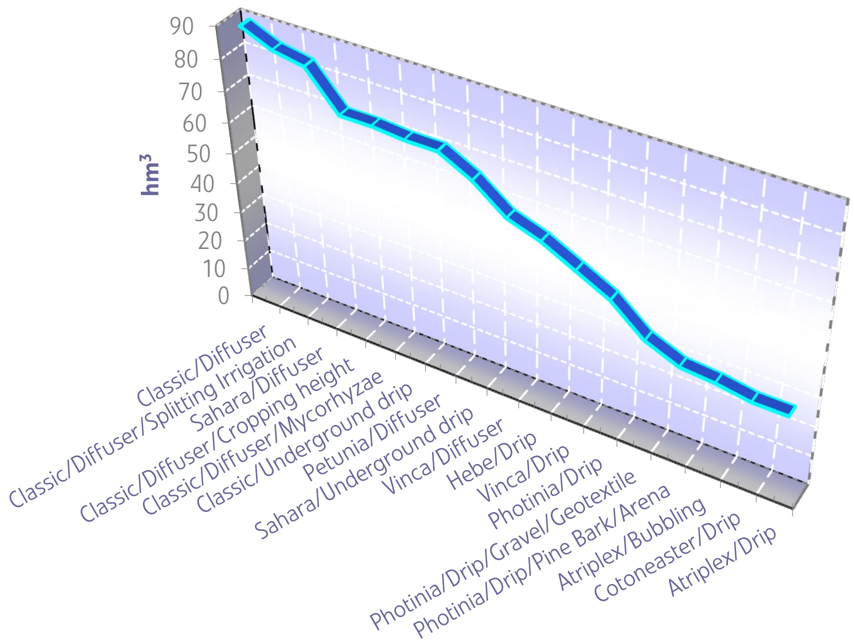
These reductions in the volumes of water required for irrigating green zones fall within the same ranges as yielded in the results of other studies conducted in the United States, in which detached houses were monitored after they had replaced their lawn gardens with xerogardens.

In view of these results, if the 10,000 hectares of lawn in the Region of Comunidad Autónoma de Madrid are replaced with shrubs with local irrigation and mulching, this would reduce by between 35 y 60 hm^3 per year, the current demand of 90 hm^3 of water for outdoor uses, which would amount to an annual saving in maintenance and water costs of around 500 million Euros per year for the park and garden owners.

Figure 2 shows how the irrigation needs for the 10,000 hectares of lawn in the Region of Comunidad Autónoma de Madrid evolve when applying different combinations of species, local irrigation and mulching.

This booklet encloses a practical manual in the form of an Appendix; it contains information about decision making when it comes to users planning, implementing and carrying out maintenance work. It is entitled: "**Guía de Jardinería Eficiente**" (Guide to Efficient Gardening).

Figure 2. Water consumption per species and technology compared with 10,000 hectares of lawn irrigated with diffuser/sprinkler



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