# Optimizing Rain Harvesting for Mediterranean Climate

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*Abstract:* - Most of the urban landscaped areas are watered with drinking water from the city utility. This represents a waste of energy used to pump the water all the way into urban areas, as well as a waste of chemicals and energy used to purify the water for human consumption. This paper analysis the feasibility of harvesting rainwater over buildings in Mediterranean climate, and storing them, for use in irrigation. The results indicate that a typical house can annually save between 3000 and 11000 l of water through rain harvesting. A simulation model is elaborated that can calculate optimize the relation between catchment area, irrigated area and tank size, based on daily rainfall and evapotranspiration of a five year period.

*Key-Words:* - Rain Harvesting, Irrigation, Water conservation, landscape irrigation, Evapotranspiration (6 - 10 words)

## 1 Introduction

Irrigating landscaped areas with municipal water is not only expensive, but also very wasteful, since energy has been used to filter and purify potable water as well as pumping it long distances from the source into urban areas. Capturing rain during rainy season and then using it for irrigation can lead to significant energy saving, and decrease water shortage problems in urban centers.

The Mediterranean climate is characterized by a rainy season (November-April) during which surplus water can be stored followed by six months of high water demand with little rainfall. This temporal separation between the rainy and the irrigation seasons is seen as a drawback to the use of these systems in the Mediterranean climate, and has meant that they are not as popular as in northern Europe.

The aim of this paper is to study the feasibility of rain harvesting under actual Mediterranean climate and optimize system geometry for irrigating small landscaped areas in domestic settings.

## 2 Problem Formulation

Rain harvesting and storage is a logical way of recycling rain water and decreasing the use of municipal water. An added advantage is that by storing rainfall, the peak run-off in urban areas is reduced, resulting in decreased floods [3] .

The basic rainwater harvesting system consists of four components: catchment, conveyance, storage, and delivery.

The catchment consists basically of the house roof, and the intercepted water is conveyed through the usual drainage pipes to a storage which can be either an above-ground or underground tank. This water is then pumped and used to irrigate the garden.

In the Mediterranean climate the rainfall is concentrated in a six month period, so it is generally considered that very large storage tanks are necessary to last through the dry season. Since storage is the most expensive part of the system, its size should be optimized in order to obtain maximum water saving.

This paper will study the rainfall and irrigation needs of a typical house over a five year period, and establish an algorithm for establishing the optimum dimension of the storage tank based on the size of the other two parameters: catchment and landscaped areas.

# 3 Problem Solution

## 3.1 Description of Model

Daily rainfall data for five consecutive years, as well as daily Evapotranspiration were used to simulate water collection, use and storage in a tank. A five year period was used in order to encompass the annual rainfall variation.

Evapotranspiration was calculated by the Penman-Monteith Equation using climate data from Divor Weather Station [1] [2]. Rainfall and Evapotranspiration data are shown in Fig.1. An average Crop Coefficient, *Kc*, of 0.7 was used to establish Crop Evapotranspiration, *ETc*, although the recommended value is 0.8. The value of *Kc* was reduced since landscaped areas around houses are usually protected from wind and all-day direct sunshine.

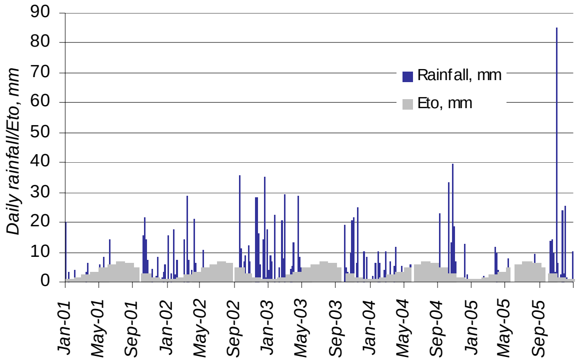


Figure 1. Daily rainfall and Evapotranspiration for the Divor Station.

Daily rainfall for the five year period was also compiled from the Divor Weather Station. It was considered that daily rainfall, P, of less than 1 mm did not produce any runoff, R, and that the Runoff Coefficient, C was 0.95, since most roof tops are fairly sloped and impermeable. The complete roof area was used to calculate total daily water collected from rainfall, according to Equation 1, with the resulting R in liters.

$$\begin{aligned} &if \quad P < 1 \rightarrow R = 0 \\ &Else \quad R = 0.95AP \end{aligned} \qquad (1)$$

Soil water holding capacity, *Z*, as well as soil moisture depletion before irrigation, *d*, are important parameters that should be input into the model. Each irrigation event has a fixed application depth, D, which should be numerically equal to *d*, in order to replace the moisture depletion between irrigations.

The model has a time step of one day, in which the previous day's soil moisture content, *z*, is augmented by the day's rainfall and decreased according to the day's *Etc*. If soil moisture is not enough to satisfy the *Etc* needs, then the area is irrigated. On the other hand, excess water beyond *Z* is not infiltrated.

$$\begin{aligned} &z_i = z_{i-1} + P_i - ETc_i \\ &if \quad z_i < d \rightarrow z_i = z_i + D \\ &if \quad z_i > Z \rightarrow z_i = Z \end{aligned} \qquad (2)$$

Irrigation water, *w*, is primarily provided by the Storage tanks. If however water stored in the tanks, *S*, is not enough to satisfy irrigation needs, than municipal water, *M*, will be used to complete the irrigation needs.

$$\begin{aligned} &S_i = S_{i-1} - D \\ &if \quad S_i < 0 \rightarrow S_i = 0 \\ &M = D - S_{i-1} \end{aligned} \qquad (3)$$

## 3.2 Simulation Results

The model was run for the period between 1 Jan 2001 and 31 Dec 2005. The simulations included various building footprints (25-500m$^2$), Tank capacities (0.5-6m$^3$), and landscaped areas (5-100m$^2$).

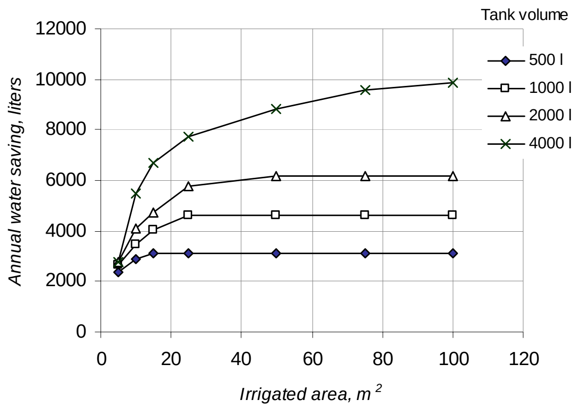


Figure 2. Annual water saving obtained from a 100m$^2$ catchment when using different irrigated areas and tank sizes.

The results indicate that, for a fixed catchment area of 100m$^2$, the water saving obtained with each tank size increases with the irrigated area up to a point, after which there is no further water saving (Fig.2). Thus, and for example, the 1000 l tank should not be used for areas above 30m$^2$, as beyond that point it does not result in additional water saving.

In case the landscaped area is pre-established, it is possible to optimize the catchment area and tank capacity for the given landscaped area. Fig. 3 presents annual water saving for a fixed irrigated area of 50m$^2$ obtained by using tanks and catchment areas of various dimension. The results show that water saving increases with both tank size and catchment area, thus there is no upper limit to the benefit obtained by increasing these parameters. Nevertheless, the marginal savings from using larger tanks decreases when using tanks that are larger than 2000 l.

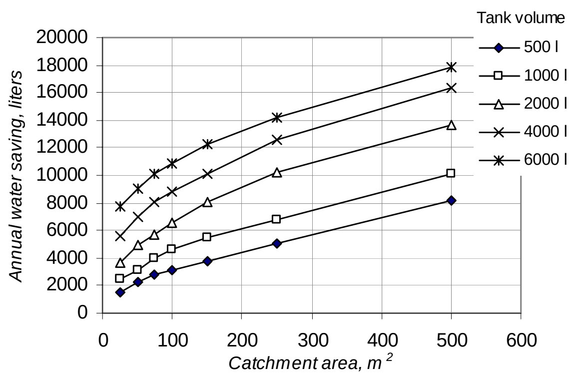


Figure 3. Annual water saving obtained when irrigating a 50m$^2$ landscaped area from different catchment areas and tank sizes.

## 4 Conclusion

The results from this simulation model indicate that significant water saving can be obtained in the Mediterranean region by domestic harvesting of rain, and its use in irrigating lawns and other landscaped areas adjacent to the house. For a typical house with a 100m$^2$ footprint and a 50m$^2$ lawn, it is possible to save between 3000 and 11 000l of water, which represent between 12 and 41% saving on the water bill.

It was shown that the tank size should be optimized according to the landscaped area, in order to maximize water saving. For example, for a 100m2 irrigated area, it is advantageous to use a larger 4000 l tank.

For large catchment areas, the marginal benefits from a larger tank decrease after a certain size. For example in catchment areas that are bigger than 100 m$^2$, the marginal water saving decreases when using tanks larger than 2000 l.

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