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Concepts, tools, and procedures necessary to implement irrigation management in Urban Green Areas

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Abstract: - Sound irrigation management requires a knowledge and understanding of the interaction of plants, soils, and climate. Water conservation is a technical goal of irrigation management that relies upon techniques that maximizes the efficiency of an irrigation system. Certain concepts and methods of water conservation may be unfamiliar to some landscape design and maintenance personnel. Irrigation managers should understand and implement the concepts and the techniques necessary for water conservation in urban green areas.

Key-Words: Water concervation, Urban green areas, Irrigation Management,

1 Introduction

Sound irrigation management requires a knowledge and understanding of the interaction of plants, soils, and climate. Water conservation is a technical goal of irrigation management that relies upon techniques that maximizes the efficiency of an irrigation system.

The objective of this paper is to provide landscape design and maintenance personnel with the concepts, tools, and procedures necessary to implement irrigation management.

2 Materials and methods

2.1 Definitions

Evapo-transpiration (ET), reference evapo-transpiration (ETo), and plant (or crop) coefficients (AKc). Evapo-transpiration (ET) is a term used to describe the water requirements of plants based upon prevailing conditions of solar exposure, temperature, and wind. Et refers to the total amount of water taken up by a plant and utilized through transpiration and evaporation. Reference Evapo-transpiration (ETo) is the water requirement of well irrigated, 4" to 8" tall fescue in full sun. Plant coefficients (AKc) are the estimated percentage of ETo that a particular species needs to maintain acceptable health and are an estimated percentage of Eto [1].

With this information the landscape manager can apply the correct amount of water necessary to maintain a planting in a healthy condition without waste.

The uniformity of an irrigation system is determined by measuring irrigation application distribution over a given area. High uniformity implies an even, uniform rate of application over each square foot of surface area. For shallow rooted plants (i.e. turf and groundcovers), uniformity is important for maximum benefit of irrigation.

Uniformity becomes more critical under drought conditions, as Greece, because of limited water availability. Plantings being maintained close to stress levels need a uniform application to ensure minimum water requirements are being provided to all the plants.

Irrigation uniformity can improve through pressure regulation and adjustment, nozzle adjustments, and avoiding irrigation during windy conditions [2].

Irrigation efficiency is the measure of the amount of water stored in the root zone divided by the amount of water applied during an application. Optimizing irrigation efficiency will provide the irrigation manager with the tools necessary for maximizing water conservation and plant health [2].

Infiltration is the movement of water into the soil. The rate of infiltration is affected by soil texture, soil moisture, and factors such as compaction or steepness of slope.

Following figure 1 showing average infiltration rates for various percentages of slopes.

Soil Texture	Infiltration Rate (inches per hour) Slope Percentage				
	0-4%	5-8%	8-12%	12-16%	>16%
Coarse sand	1.25	1.0	.75	.50	.31
Fine sand	.94	.75	.56	.38	.24
Sandy loam	.75	.60	.45	.30	.19
Loam	.54	.43	.33	.22	.14
Clay loam	.25	.25	.15	.10	.06
Clay	.10	.09	.08	.05.	.03

Figure 1. *Average infiltration* rates for various percentages of slopes[3]

Soils act as water reservoirs for plants by storing water until water is taken up through roots. The amount of water available to a plant can be estimated by knowing the depth of the root system and the texture of the soil. A soil holds its maximum amount of water when it is said to be at 'field capacity' or the level of soil moisture that remains in the soil after gravity has drained excess water. Most soils will be at field capacity within a day after strong rain storms or deep irrigations. The allowable depletion refers to the amount of water that is available to the plant for use. A plant is able to extract only a portion of the water held by the soil due to the attraction of the water to soil particles. The following figure 2 shows the water storage capacity and allowable depletion amounts of various soils at field capacity.

Soil Texture	*Total Water Holding Capacity	*Amount Available (Allowable Depletion)	*Average Allowable Depletion
Sand	0.6-1.8	0.4-1.0	.75
Sandy loam	1.8-2.7	0.9-1.3	1.1
Loam	2.7-4.0	1.3-2.0	1.7
Silt loam	4.0-4.7	2.0-2.3	2.1
Clay Loam	4.2-4.9	1.8-2.1	2.0
Clay	4.5-4.9	1.8-2.1	2.0

Figure 2. *Water storage capacity* and allowable depletion amounts of various soils [4]

*(Inches of water per foot of soil depth, An inch of water covers the surface one inch deep)

As shown in the figure 2 clay soils can hold up to 4 times the water than in sandy soils, though the water available to the plant is only twice the amount. These differences in water holding capacity and allowable depletion influences the amount of water to be applied as well as the frequency of application.

2.2 Site and design Factors to consider when planning an irrigation system.

A successful irrigation system must start with a practical and workable design. Following are elements of irrigation system planning that must be considered during the design process. Effective irrigation management requires a design that is site specific and efficient in its delivery.

I. Utility and Connection

a. Establish water source and point of connection

b. Evaluate water quality for appropriateness to plant selection and for possible restrictions on type of irrigation equipment (i.e. drip irrigation).

c. Determine:

- type, size, and length of meter service piping
- meter type
- static water pressure
- requirements for back-flow prevention devices, booster pumps, well pumps, or master valves
- electrical power sources
- existing water line cross overs

II. Site Characteristics

a. Soils information

- soil texture and infiltration rate
- drainage and percolation information (cut slopes, compaction, hard pans, etc.)

b. Slopes

- steepness
- length

c. Solar exposure

d. Climatic information

- wind patterns
- Eto rates (maximum flow requirements)

III. Related Landscape Design Considerations

a. plant locations and spacing requirements

b. plant selection and water requirements

c. existing physical site features (drainage, signs, pavement)
d. budget limitations

IV. Maintenance Considerations

a. equipment preferences
b. location of equipment (protection, accessibility, and worker safety)
c. Controller programming requirements
d. Separation of valving according to plant type, exposure, and slopes
e. Matched and uniform precipitation rates of sprinklers
f. Uniform operation pressures
g. Special irrigation management equipment i.e. soil moisture sensors, rain and wind sensors, etc.
i. Locating irrigation components to avoid damage and vandalism j. Prevention of excessive low head drainage

2.3 Irrigation system components useful for water

Matched-precipitation sprinklers- Sprinklers with matched precipitation rates will help ensure uniformity of the application. Proper performance is dependant upon correct spacing and consideration of wind or other site conditions such as slopes.

Low-precipitation sprinklers- Low precipitation rates will help match irrigation application rates to soil infiltration rates and avoid problems of runoff. Rates should be close to 1/2" per hour and are effective for irrigating slopes or sites with fine textured soils

Automatic controllers- Automatic controllers, and especially electronic (solid state) models, allow for flexibility of programming to permit precise control of irrigations. Features include the ability to schedule multiple cycles for control of runoff and to use multiple programs for specific irrigation of different plant types or variable site conditions. For large sites or sections of highway, central controllers offer maximum flexibility and control of irrigation scheduling.

Rain and wind sensing devices- These devices are designed to prevent irrigation when weather conditions are inappropriate for irrigation. Wind devices will shut down the system when wind speeds are above a pre-determined amount, while rain sensors will prevent the system from operating during rain periods. Cycles can be temporarily suspended or reset to begin at the next irrigation start time.

Moisture sensing devices- Moisture sensing devices can save significant amounts of water (up to 50%) in sites having uniform soil conditions, solar exposures, and plant types,. Generally, they are designed to measure soil moisture and prevent a valve from operating when soil water is above a pre-determined level. The disadvantages include high installation costs and problems with sites having mixed site conditions.

Check valves- Check valves prevent the problem of water drainage from low elevation heads. In addition to saving water, these valves also help reduce water hammer and surge due to the introduction of air into the lines.

Master valve and excess flow-sensing device- These features help prevent loss of water from malfunctioning valves or broken irrigation lines. The master valve opens only during scheduled run times, while the excess flow sensing device will shut down the system when water flow is above normal. [5]

2.4 Choose plants for water concervation

Most literature concerning water conservation in the landscape will discuss two basic terms for describing the natural ability of plants to withstand drought. These terms are xeric and mesic. Plants that are xeric are said to be drought adaptive. Mesic refers to plants that require regular and consistent availability of water to remain healthy.

A mesic plant's water requirements can generally be assumed to be from 90% to 150% of reference evapo-transpiration (ETo). In comparison, a xeric plant might only require 20%to80% of ETo.

Xeric plants have different ways for adapting to drought and these differences are important. Some plants respond to drought by entering their dormancy period when water is no longer available. Examples of these plants include hillside grasses that grow in the winter and spring and go dormant in summer and fall. Other plants such as Acacia, Nerium, and Olea adapt to drought by reducing water loss. Characteristics of these plants include grey or grey-green foliage, small, leathery leaves, and leaf arrangements designed to limit water loss from the plant. The majority of xeric plants are Greece native plants or plants from Mediterranean climates. These plants are naturally adaptive to dry summers. It should be noted that all native or Mediterranean plants are not necessarily drought tolerant and that there is often a great difference in this respect.

This second type of xeric plant, while requiring less water, must, in most landscape situations, receive at least limited amounts of water to stay healthy. The most important factor in this regard is the amount of soil volume available to the plant. The soil acts a reservoir of water and plants with large extensive root systems can go much longer between irrigations than plants with shallow, limited root systems. It is a common misconception that most native plants can be planted, established with temporary irrigation, and then survive without further irrigation. In most landscape plantings even xeric plants will require summer irrigation, though this may only be a few deep irrigations per year.

If soils are compacted or shallow, with a corresponding shallow root system then irrigation requirements will be frequent due to the limited soil reservoir capacity. The frequency and amount of irrigations is dependant upon the depth of the root system and the soil texture.

2.5 Using Mulch to reduce water use in plants

Mulches are layers of loose organic material placed over soil and are used to reduce the evaporation of soil moisture and insulate soil temperatures. This retention of moisture allows more water to be available to plants and permits longer durations between irrigation [6].

To be effective, mulches should be applied minimally 2" thick and preferably deeper. The material most commonly used is wood chips or bark. Fibrous bark (usually redwood) is very effective for mulching slopes. The stringy texture of the mulch holds securely to the soil and does not wash away as is the case with bark chips.

The use of hay or straw is not as desirable due to high concentrations of weed seeds in these materials.

Another advantage of mulches is the reduction of weed growth. It is important a minimum depth of 2" be maintained as mulch depths less then this will not reduce weeds and can prevent the effective use of pre-emergent herbicides.

Mulches require periodic replacement due to decomposition. Generally the coarser the material the long lasting its longevity. Chips from tree pruning are a common source of mulch in roadside plantings.

2.6 The use of moisture sensors

The purpose of moisture sensors is to accurately measure soil moisture content to improve the efficiency of irrigation applications. There are two groups of moisture sensors that have been used in the landscape industry. The first measures electrical resistance through the use of either electrodes or gypsum blocks, and the second (tensiometers) measure the vacuum created as soil dries. These sensors can be used to simply measure soil moisture or, can be installed to actively override automatic irrigation systems to prevent unnecessary irrigations. Experimental results from a 1988 Caltrans study indicates potential water savings from 10% to 50%, depending upon previous irrigation scheduling

2.7 Slopes Irrigation

Slopes are particularly difficult to manage due to the problems of irrigation uniformity and special soil conditions. Just the simple fact that water moves downhill presents special problems for irrigation. The tops of slopes are often under watered while bottoms of slopes become saturated. Additionally, excessive irrigation can promote problems of erosion. In that case we choose a system that applies water slow enough to allow infiltration into the soil without runoff, while still providing sufficient uniformity of coverage.

Appropriate irrigation and design considerations for slopes include: Low and matched precipitation sprinklers. Automatic controllers that permit repeat cycling. Check valves that prevent drainage at bottom of slopes. Separate valving for sprinklers at top, middle, and bottom of slope. Separate valving and types of equipment (micro-sprays, bubblers, or sprinklers) for plants with different irrigation needs. Selection of plants specifically adaptive to slope soil and exposure conditions. Selection of plants with similar cultural and irrigation requirements. Trees and large shrub species should only be planted where there is sufficient soil to sustain healthy growth. For many sites this may only be at the base or top of the slope.

The following figure 3 is to be used to adjust slope irrigation scheduling. The use of these factors requires that sprinklers at the top, middle, and bottom of the slope be valved separately. The adjustments are based upon the steepness of the slope and the location of the sprinklers.

Location of Sprinkler on slope	**Steep (1:1/2 to 1:2)**	**Medium (3:1 to 2:1)**	**Slight (<3:1/2:1)**
Top	1.5	1.3	1.1
Middle	1.0	1.0	1.0
Bottom	0.5	0.7	0.9

Figure 3. *Slope factor table* to adjust slope irrigation scheduling [7]

These factors are simply multiplied against total run times. Length of individual cycles will still be dependant upon irrigation precipitation and soil infiltration rates and generally should not change, just the number of cycles.

3 Conclusions

The following list summarizes the items necessary to accomplish a water conservation program.

1. Evaluate soils to determine infiltration rates and water holding capacity.
2. Determine rooting depths for major plant types. Estimate relative drought tolerance of these plants and assign a crop coefficient.
3. Evaluate irrigation system to determine precipitation and uniformity rates.
4. Make necessary repairs or modifications to improve uniformity and efficiency of irrigation application. Focus on pressure and proper sprinkler selection.
5. Beginning in spring, start a water budget program designed to replace evapo-transpiration (ETo) loss modified by the assigned crop coefficient.
6. Monitor condition of plants by watching for signs of water stress.
7. Use cultural practices such as mulching and weed control to reduce water use. If required, fertilize trees and shrubs in early spring. Schedule size control pruning of fast growing shrubs in early summer. Thin out over-crowded plantings to provide more soil volume to remaining plants. Control insect and disease problems in early stages.

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