The Effectiveness of a Low-cost Soil Moisture Sensor for Domestic Irrigation Systems

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Abstract

Domestic garden irrigation often constitutes a considerable percentage of the total urban scheme water demand. Improvements in irrigation efficiency have the potential to contribute to substantial water savings within the community. Improper scheduling of irrigation systems is one of the key factors contributing to inefficient use of water in domestic irrigation systems. The application of soil moisture sensors that automate irrigation cycles can help negate the effects of poor scheduling which would other wise lead to over irrigation, resulting in the wastage of water resources and other consequential environmental impacts. A low-cost capacitance soil moisture sensor has been developed and is currently the subject of a twelve month trial at the Environmental Technology Centre, Murdoch University, Perth, Western Australia. The sensor is being assessed to determine its ability to contribute to water savings when used with shrub sprinklers, micro-spray and drip line irrigation on sandy soils, in the Mediterranean type climate that Perth experiences.

Key Words

low-cost soil moisture sensor, domestic irrigation systems, water conservation

INTRODUCTION

Domestic garden irrigation often constitutes a considerable percentage of the total urban scheme water demand. In Perth, Western Australia it is estimated as being as much as 55% (Coghlan and Higgs, 2000, 145). Inefficiencies in domestic irrigation systems can be the result of several factors including inappropriate irrigation technology, poor irrigation system design and improper scheduling. Advances in micro-irrigation technology in the agricultural sector have resulted in corresponding developments in the landscape irrigation industry in both sprinkler and dripper design.

Programmable clock driven irrigation control units are commonly used in domestic irrigation systems and it is assumed that automated irrigation systems with such controllers will save more water than manually operated systems. While this is often the case, water can still be wasted; for example, on days when the program is set to operate and rainfall occurs; when evaporation levels fall; and at times when summer programs are not switched over to winter programs. Programmable systems that are controlled with soil moisture sensors can help to overcome these problems but these have typically been expensive and not within the budget of average householders.

The FloriCOM™ is a low cost capacitance soil moisture sensor developed by the irrigation company NETAFIM®. When properly installed and calibrated, the sensor is designed to over-ride the irrigation control unit program if the soil moisture content is above the preset level. This may occur as the result of rainfall events or due to variances in weather conditions resulting in the reduced transpiration activity of plants. This paper outlines the methodology by which the sensor is assessed for its ability to contribute to water savings when included as part of a well designed domestic garden irrigation system.

SOIL MOISTURE MEASUREMENT

The concept of soil water availability assumes that a given soil can hold a certain amount of water in the root zone of plants, against gravity and flow to ground water. This amount of water is termed *field capacity*. The amount of water that is bound so tightly to the soil matrix that it can not be accessed by plants is termed *permanent wilting point*. The difference between the two is called the *available field capacity* which is expressed as a percentage (Schmitz and Sourell, 2000, 147). Soil moisture sensors can be used to determine the appropriate interval between irrigation, the depth and accuracy of wetting and the depth of extraction by plant roots (Hanson *et al.,* 2000, 38). Irrigation scheduling by monitoring the soil water content means that as soon as the lower limit of the water content is reached, the soil can be replenished with water to an upper limit, with the goal being to supply adequate water to plants whilst avoiding the wasting of water by having it percolate pass the root zone (Schmitz and Kuyper, 1998, 87).

A number of instruments for measuring soil water content have been developed such as tensiometers, resistance blocks (gypsum block and granular matrix sensors), wetting front detectors, neutron moderation, heat dissipation and soil dielectric instruments. While soil moisture sensors usually work well under laboratory conditions, they can often perform poorly in the field (Schmitz and Kuyper, 1998, 87, 88). This is attributed to problems with spatial variability such as non-uniform irrigation, variations in soil uniformity and the non uniform extraction of soil water by plant roots. Recent studies by Proulx *et al*. (1999), Schmitz and Sourell (2000) and Hanson *et al*. (2000) on the comparison of the major commercial models of sensors, representing each category of soil moisture monitoring equipment, show that performances will vary with soil type and soil salinity and are often unreliable.

The FloriCOM™ soil moisture sensor is a frequency domain reflectometry, or capacitance soil moisture sensor. Capacitance sensors determine soil moisture content by measuring the dielectric constant of soil (Hanson and Peters, 2000, 43). The dielectric constant is a measure of the capacity of a non-conducting material to transmit electromagnetic waves or pulses. The dielectric constant of dry soil is much lower than that of water, with small changes in the quantity of free water in the soil having large effects on the electromagnetic properties of the soil water medium (Charlesworth, 2000, 6). Capacitance sensors, consist of two electrodes separated by a dielectric. Placing the electrodes in the soil results in the soil becoming part of the dielectric. A high frequency electrical pulse applied to the electrodes causes a resonant frequency, which is then measured by the instrument. This frequency changes as the dielectric constant of the soil changes (Hanson and Peters, 2000, 43).

Despite the wide array of soil moisture sensors available in the market, very few studies comparing soil moisture sensors have been reported in the literature (Proulx *et al.,* 1999, 3). This is particularly relevant to soil moisture sensors for landscape irrigation. Soil moisture sensors have been employed mostly in agriculture where their investment is warranted due to the scale and value of crops, as well as the costs involved with using large quantities of water and the energy required to pump it (Qualls *et al.,* 2001, 548). There has been continued work on developing soil moisture sensors that are functional, easy to operate and inexpensive (Nadler and Lapid, 1996, 361) which is subsequently making the technology more accessible to the landscape irrigation market.

In a study undertaken by Zazueta *et al*. (1994), comparing the effectiveness of rainfall shut-off devices to soil moisture sensors for domestic garden irrigation systems (under simulated conditions), the soil moisture sensors were shown to be more effective in saving water. The simulated results showed that the application of rain simulation devices reduced irrigation water use by 20% to that of the control irrigation schedule, whilst the soil moisture sensor reduced irrigation water use by 30% (Zazueta *et al.,* 1999, 867). Qualls *et al.,* (2001) noted considerable water savings in their study using resistance block sensors to control urban landscape irrigation in Boulder, Colorado, USA. A relatively inexpensive granular matrix soil moisture sensor was used to override a standard clock driven irrigation program. The results of the study indicated that the granular matrix sensors were successful at saving water and were cost effective to operate (Qualls *et al*., 2001, 553). Due to granular matrix sensors being unreliable in sandy soils (Charlesworth, 2000, 24), the model trialed by Qualls *et al*. (2001) is not likely to be suitable for Perth, Western Australia, where the majority of urban development is along the Swan Coastal Plain, which is characterized by deep sandy soils (Aylmore *et al*., 1994, 3).

TRIAL METHODOLOGY

The performance of the NETAFIM® FloriCOM™ soil moisture sensor is currently being trialed at the Environmental Technology Centre (ETC), Murdoch University. The trial will be conducted over a 12 month period (January – December 2002) and will allow for the assessment of the sensors performance when used in association with three common domestic irrigation systems, namely shrub sprinklers (Rain Master® Shrub Spray Nozzles™), micro sprays (Philmac® "J" Series™) and drip irrigation (NETAFIM® Miniscape™ drip line).

It is intended that the trial of the FloriCOM™ at the ETC will allow for the analysis and discussion of:

1. The ability and reliability of the sensor to respond to variations in soil moisture as the result of rainfall events or reduced evaporation / plant transpiration activity brought about by changes in the weather.

2. Potential variations in the performance of the sensor when used with shrub sprinkler, micro spray or drip irrigation systems.

3. The impact of the sensor controlled irrigation system on plant performance on sandy soils.

4. The difference in water usage between the three irrigation systems when providing for the basic water needs of the plants in the trial plots.

The trial site consists of six plots measuring 4m x 4m each, aligned in series along a north-south axis, each being separated by a two-metre buffer zone as well as partitioning screens to prevent irrigation from drifting to neighbouring plots. The soil type of the trail site is a uniform coarse siliceous sandy type typical of the Perth Swan Coastal Plain landform feature. One hundred millimeters of top soil has been excavated from the surface to remove the inconsistent “A horizon” containing organic matter and seed store. The trial plots have been mulched so as to best represent the conditions of a garden bed. The mulch is a screened pine bark type and has been applied by a commercial mulch blower so as to achieve a uniform layer of 50 mm over the surface of all six plots.

The plots have been further divided into sixteen 1m^2 quadrates with each quadrate having been planted with the same species of perennial shrub - *Westringia viminalis,* variety "White Rambler." The criteria for the selection of the shrub species being: hardy shrub suited to sandy soils, full sun and exposed conditions; vigorous growing; low habit so as not create irrigation shadows over plants in the same trial plot; established plants (5L pot size) being from similar parent stock. Each plot received the same fertiliser application at planting and will do so throughout the duration of the trial.

Two plots are serviced by shrub sprinklers, two by micro spray and two by drip line irrigation (installed as per the manufacture’s specification), with the water to each plot being supplied by an independently controlled clock driven programmer, valve and metered irrigation line. One of the plots in each pair has a soil moisture sensor installed whilst the neighbouring plot of the same irrigation type does not (the control). All six plots are also serviced by an additional independent metered irrigation line with agricultural sprinklers to provide an identical irrigation regime during the establishment phase of the shrubs.

The irrigation scheduling has been set to provide an appropriate amount of water to the shrubs in the plots by taking into consideration the water holding capacity of the soil at the site, the average root depth of the shrubs, the crop factor of the selected shrubs, the peak summer Pan A evaporation data for Perth, a management allowable deficit of 50%, as well as the different application rates and distribution uniformity (DU) characteristics of the three irrigation systems. The same irrigation scheduling will be maintained for the duration of the trial.

The irrigation lines servicing each plot are individually metered using standard Water Corporation of Western Australia issue PSM LT class four cold potable water meters with a pulse output capability and water use is recorded on a data logger. It is assumed that when the water meters associated with soil moisture sensor equipped programmable control units record a water flow reading, the irrigation cycle is operating as scheduled. When the sensor equipped programmable control units do not record a water flow reading when they are programmed to operate, it is assumed that the programmed schedule has been over ridden. Local rainfall and evaporation rate data is recorded at the adjacent Murdoch University Meteorological Station and is used to account for the external environmental factors that influence the performance of the soil moisture sensors.

The plant moisture stress (PMS) method, also known as the plant water potential, has been employed to determine if the plants in each plot are receiving adequate irrigation. The PMS method indicates the demand for water within a plant, integrating the soil moisture tension in the root zone (i.e. the suction that plants must exert to access available free soil moisture), the resistance to water movement within the plant and the demands for transpiration imposed by the environment. It is intended that this method will conclude whether the three different irrigation systems are irrigating the shrubs in the corresponding trial plots effectively under the conditions of the trial site, and if the plots that are irrigated with soil moisture sensor equipped programmable irrigation control units are receiving adequate water.

CONCLUSION

Despite the fact that domestic irrigation often constitutes a considerable percentage of total urban scheme water demand, there appears to be limited research undertaken in the application of new soil moisture sensor technologies to improve landscape irrigation water use efficiency. Significant advances have been made in this area within the agriculture sector which is contributing to making the technology more accessible to the domestic market. Studies done to date suggest that many commercially available sensors are unreliable.

Soil moisture sensors have the potential to contribute to considerable water savings if incorporated into domestic irrigation systems, in particular helping to overcome the wastage of water as a result of poor irrigation scheduling. The FloriCOM™ capacitance soil moisture sensor is low a cost unit that is currently under trial at the Environmental Technology Centre at Murdoch University. The sensor is being tested for its ability to contribute to saving water when included as part of a well designed domestic irrigation system on sandy soils, in the Mediterranean type climate of Perth. The trial will run from January to December 2002.

The experimental setup has been designed to test if the soil moisture sensor will prevent unnecessary irrigation without compromising the soil moisture requirements of the indicator shrubs. Furthermore, it is intended that the trial will demonstrate the ability of the sensor to operate reliably when used in association with three different common types of garden irrigation systems. It will also be possible to determine which type of irrigation system is most suitable for providing for the basic water needs of the shrubs in terms water use efficiency. It is expected that the use of drip line irrigation, combined with a soil moisture sensor equipped programmable control unit, will be the most water efficient method to irrigate. Preliminary results show that the greatest water savings can be achieved when using drip line irrigation with the inclusion of a soil moisture sensor as part of a well designed irrigation system. The water savings brought about by using the drip line - sensor combination does not appear to compromise plant performance to any significant degree. The full findings of the trial will be available in December 2002.

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